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THESIS

CORRELATION OF READY FOR TASKING TO FULL MISSION CAPABLE METRICS FOR F/A-18E/F

by

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March 2013

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Historically, the U.S. Navy has utilized Full Mission Capable (FMC) as the standard metric in assessing aviation readiness, but an alternative to FMC has been introduced by air wing commanders: Ready for Tasking (RFT). RFT is a less demanding standard for readiness that provides a better representation of mission success than FMC. Since FMC is used as an input to aviation repairable sparing models, before RFT can replace FMC in funding models it is necessary to analyze the linkage between RFT and FMC.

This thesis explores the relationship between RFT and FMC based on five years of data from the East Coast Carrier Air Wings flying F/A-18E/F Super Hornets. Linear and logistic regression models are developed to analyze the impacts 11 common variables have on RFT. It also examines readiness trends throughout the Fleet Response Training Plan.

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CORRELATION OF READY FOR TASKING TO FULL MISSION CAPABLE METRICS FOR F/A-18E/F

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ABSTRACT

Historically, the U.S. Navy has utilized Full Mission Capable (FMC) as the standard metric in assessing aviation readiness, but an alternative to FMC has been introduced by air wing commanders: Ready for Tasking (RFT). RFT is a less demanding standard for readiness that provides a better representation of mission success than FMC. Since FMC is used as an input to aviation repairable sparing models, before RFT can replace FMC in funding models it is necessary to analyze the linkage between RFT and FMC.

This thesis explores the relationship between RFT and FMC based on five years of data from the East Coast Carrier Air Wings flying F/A-18E/F Super Hornets. Linear and logistic regression models are developed to analyze the impacts 11 common variables have on RFT. It also examines readiness trends throughout the Fleet Response Training Plan.

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LIST OF ACRONYMS AND ABBREVIATIONS

A/C	Aircraft
ACWT	Average Customer Wait Time
APN	Aircraft Procurement, Navy
ARROWs	Aviation Readiness Requirements Oriented to Weapon Replaceable Assemblies
COMNAVAIRLANT	Commander, Naval Air Force Atlantic
COMPTUEX	Composite Training Unit Exercise
COTS	Commercial Off-the-Shelf
CNAF	Commander Naval Air Forces
CSG	Carrier Strike Group
CVW	Carrier Air Wing
DoD	Department of Defense
FAA	Federal Aviation Administration
FHA	Flight Hours Accomplished
FHRS	Flight Hours
FLA	Flight Line Assigned
FMC	Full Mission Capable
FRTP	Fleet Response Training Plan
FY	Fiscal Year
HQ	Headquarters
IFF	Identify Friend or Foe
IMC	Instrument Meteorological Conditions
LMI	Logistics Management Institute
MOP	Measure of Performance
MTBF	Mean Time Between Failure
NAS	Naval Air Station
NATOPS	Naval Aviation Training and Operating Procedures Standardization

NAVAIR	U.S. Navy Naval Air Systems Command
NAVSUP	Naval Supply Systems Command
NWCF	Navy Working Capital Fund
OEM	Original Equipment Manufacturer
OPAREA	Operating Area
OPTEMPO	Operational Tempo
POM	Pre-/Post- Overseas Movement
RBA	Ready Basic Aircraft
RECON	Reconnaissance
RFT	Ready for Tasking
SMA	Supply Material Availability
SPO	Service Planning and Optimization
TFHR	Training Flight Hours
T/M/S	Type/Model/Series
VFA	Fixed Wing Fighter Attack
WSS	Weapons Systems Support

EXECUTIVE SUMMARY

Historically, the U.S. Navy has utilized Full Mission Capable (FMC) as the standard metric in assessing aviation readiness. Appendix A of the Naval Aviation Maintenance Program defines FMC as the "material condition of an aircraft that can perform all of its missions" (CNAF 4790.2B Appendix A 2012). FMC has trended downward since the mid-2000s while air wing commanders and other stakeholders have endorsed Ready for Tasking (RFT) as an alternative to FMC. RFT is a less demanding standard for readiness that provides a better representation of mission success than FMC. For an aircraft (A/C) to be designated FMC, it must be able to perform all of its missions including those the commander does not require during a given sortie. In contrast, RFT only involves the fraction of A/C that can perform required missions; hence if an A/C has a deficiency in a configured mission that is not currently needed, the A/C is rated as RFT but not FMC. The commander's main focus only regards those missions required for a given sortie, thus commanders prefer RFT over FMC as a gauge for readiness.

FMC is used as an input to aviation repairable sparing models including Aviation Readiness Requirements Oriented to Weapon Replaceable Assemblies (ARROWs) and Service Planning and Optimization (SPO), thus it is necessary to analyze the linkage between RFT and FMC before FMC can be discarded as a readiness metric in favor of RFT. Utilizing data covering March 2007 through June 2012 from F/A-18E/F Super Hornet squadrons home-ported at Naval Air Station (NAS) Oceana in Virginia Beach, VA, the relationship between RFT and FMC is examined in addition to other variables common in naval aviation. These variables include RFT Entitled, Ready Basic A/C (RBA), Flight Hours Accomplished (FHA), Flight Hours Entitled (FHRS Entitled), Training Flight Hours Entitled (TFHR Entitled), Assigned A/C, Flight Line Assigned (FLA), FLA Entitled, Wing, and Phase. It is important to note that RFT Entitled for a wing is based on the number of A/C within the wing in addition to the month/phase within the Fleet Response Training Plan (FRTP), thus it is a moving target. When more missions are required, RFT Entitled is higher. A logistic regression model is generated to predict when a wing fails to achieve a perfect RFT during a month. Then employing only

observations where a wing achieved less than a perfect RFT (1.00) during a month, a multiple regression model is fit to determine the effects variables have on RFT.

Of 293 wing/month combinations, 212 (72.4%) achieved the goal of a perfect RFT although the average FMC of 0.52 fell below the overall standard for the Super Hornet (Buckley et al. 2011). Of 74 deployed observations, 28 achieved the FMC standard of 0.63 (37.8%), while 97 of 219 non-deployed observations attained the non-deployed FMC standard of 0.53 (44.3%). The respective RFT achievements for deployed and non-deployed were 60 (81.1%) and 152 (69.4%), thus wings are doing a much better job meeting RFT goals compared with FMC as it is significantly easier to attain RFT than FMC. When viewing readiness through the RFT lens the Fleet is performing relatively well, but assessing readiness with an FMC perspective leads to a different conclusion.

The correlation between RFT and FMC was 0.17, which represents an undetermined relationship. There was a negative correlation in two of the five wings analyzed: as FMC went down, RFT went up. This is counterintuitive (both RFT and FMC measure readiness) since if readiness goes up, then readiness indicators should rise as well. One explanation for the lack of a stronger linear positive relationship is due to excess readiness available in RFT that is not available for FMC. When RFT and FMC are utilized as fractions, all A/C rated FMC contribute towards the FMC fraction while only those A/C rated RFT capped off at RFT Entitled count towards the RFT ratio. The following illustrates the very weak connection between RFT and FMC: of 14 observations where FMC dropped below 0.20, eight (57.1%) achieved a perfect RFT including the lowest value of FMC observed (0.07). Clearly the relationship between RFT and FMC is very weak: other factors are involved that create complex relationships.

A 2011 Logistics Management Institute (LMI) study found a negative trend in FMC values for overall Type/Model/Series (T/M/S) A/C since 2006 (Buckley et al. 2011). The correlation coefficient between month/year and FMC for the 293 observations was -0.60, and at a significance level of 5% FMC for East Coast Super Hornets have trended down from March 2007 to June 2012. The correlation between month/year and RFT was only -0.01 which represents an inconclusive linear relationship. All five wings analyzed had statistically significant differences in FMC accomplishment

by year. RFT differences by year overall are not significant as only three of the five wings' success rates were affected by the year.

The selection of an official readiness metric can make a difference when comparing wings to one another. If achieving an RFT of 1.00 during deployment is the ultimate goal, CVW-17 had the highest readiness of the five East Coast air wings during this five year period. However, if meeting an FMC standard of 0.63 during deployment is the measuring stick, CVW-17 had the worst readiness. Thus it is critical to select an appropriate readiness metric and while the commander may simply desire to accomplish the mission, one can better detect trends and patterns with FMC than via RFT.

A logistic regression model was generated to predict when a wing fails to achieve a perfect RFT during a month. The naïve Bayes rule predicts a perfect RFT for each observation since the majority (72.4%) of observations attained an RFT of 1.00. Compared with the naïve Bayes rule's misclassification of 81 observations (predicting a perfect RFT when the observation achieved an RFT < 1.00 and vice versa), this logistic regression model misclassified 48 which represents a 40.7% reduction in errors. This model also reduced misclassifications within each wing compared with Bayes. FMC was retained in the model in addition to its interactions with Wing and FHRS Entitled, while the phase had no impact on achieving a perfect RFT. Since the phase helps determine the entitlements, the presence of entitlements within the model allows for phase to be left out. FLA, FHA, and RFT Entitled were also unnecessary, while the only other interaction required was between Assigned A/C & Wing.

Employing only observations where a wing achieved less than a perfect RFT (1.00) during a month, a multiple regression model was fit to determine the impacts variables have on RFT. RFT was transformed four different ways in an attempt to achieve homoscedasticity and FMC was unnecessary in the presence of the other variables in all models. The best model's adjusted R-Squared statistic was 0.6293, thus this model explained 62.93% of the variation. FHA also fell out of the best model while the only interactions required were between Assigned A/C & Wing and between FHRS & Phase.

There appears to be value in retaining both RFT and FMC as readiness metrics: if the primary concern is accomplishing missions when required then RFT has a purpose, while FMC is useful to portray readiness trends and as a funding input. Employing RFT as an input for aviation spares funding models could have significant fiscal effects if a perfect RFT goal is utilized since this thesis found 72.4% of observations meeting the goal.

Finally, only Super Hornets supported via Naval Air Station Oceana during March 2007 through June 2012 were considered for this analysis. Alternative T/M/S, support locations, or time frames may produce contradicting conclusions. In addition, the relationship between RFT and Supply Material Availability could be explored in follow-on studies.

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I. INTRODUCTION

Historically, the U.S. Navy has utilized Full Mission Capable (FMC) as the standard metric in assessing aviation readiness. Appendix A of the Naval Aviation Maintenance Program defines FMC as the "material condition of an aircraft that can perform all of its missions" (CNAF 4790.2B Appendix A 2012). Beginning in 2009, all naval aircraft (A/C) considered in the aggregate were no longer achieving the FMC standards, while the Super Hornet has not achieved its FMC standard since 2000 (Buckley et al. 2011). As aviation units fail to meet a standard Measure of Performance (MOP), the Fleet has introduced an alternate MOP - Ready for Tasking (RFT). RFT is a less demanding standard for readiness that provides a better representation of mission success than FMC. For an A/C to be designated FMC, it must be able to perform all of its missions including those the commander does not require during a given sortie. In contrast, RFT only involves the fraction of A/C that can perform required missions; hence if an A/C has a deficiency in a configured mission that is not currently needed, the A/C is rated as RFT but not FMC. The minimum RFT requirement is driven by the number of A/C within the wing and the month/phase within the Fleet Response Training Plan (FRTP), thus it is a moving target (CNAF INSTRUCTION 3510 series 2006). The commander's main focus only regards those missions required for a given sortie, thus RFT provides a better gauge for operational readiness than FMC. The transition towards RFT has evolved to the point where the Navy has not established FMC standards for the next generation Joint Strike Fighter (Buckley et al. 2010).

FMC is used as an input to aviation repairable sparing models including Aviation Readiness Requirements Oriented to Weapon Replaceable Assemblies (ARROWs) and Service Planning and Optimization (SPO), thus it is necessary to analyze the linkage between RFT and FMC before FMC can be discarded as a readiness metric in favor of RFT. Utilizing data covering March 2007 through June 2012 from F/A-18E/F Super Hornet squadrons home-ported at Naval Air Station (NAS) Oceana in Virginia Beach, VA, the relationship between RFT and FMC is analyzed. The relationships of RFT and FMC to other variables common in naval aviation are also examined. These variables

include RFT Entitled, Ready Basic A/C (RBA), Flight Hours Accomplished (FHA), Flight Hours Entitled (FHRS Entitled), Training Flight Hours Entitled (TFHR Entitled), Assigned A/C, Flight Line Assigned (FLA), FLA Entitled, Wing, and Phase. A mixture model is fit to explore the relationship between these variables and RFT. This mixture model has two components. The first component is a logistic regression model generated to predict when a wing fails to achieve a perfect RFT during a month. The second component is a multiple regression model that is fit to only those observations where a wing achieved less than a perfect RFT (1.00) during a month. Finally, RFT and FMC trends over FRTP phases are analyzed and presented graphically.

The Super Hornet is the focus of this study for two reasons. The first reason is the Super Hornet is the most modern naval A/C in operation where ample data exists, and it replaces several legacy platforms. The second reason is its wide array of missions including fighter escort, close air support, armed reconnaissance, aerial refueling, and precision strike among others. The Super Hornet can fail to meet its aerial refueling mission but still be considered RFT if the mission of the day is precision strike. Hence, RFT for a Super Hornet is not necessarily the same as FMC and the differences between these metrics can be analyzed.

The R statistical computing software is used for this thesis. R is a free software program produced by the R Foundation for Statistical Computing located in Vienna, Austria. It is a collaborative programming language with many contributors, and further information can be located at http://www.R-Project.org/ (R Core Team 2012).

A. BACKGROUND

1. The Distinction between FMC and RFT

An A/C is designated FMC when it can complete all missions it is designed to perform. An A/C is designated RFT when it can perform the particular mission it is assigned during a sortie. The Fleet considers RFT a better reflection of operational readiness than FMC since squadron commanders' main concerns rest in completing specific missions. If the mission requires one A/C for an armed reconnaissance (RECON) sortie when only one of 10 A/C possesses this capability, commanders can report RFT at 100% instead of a 10%

FMC assuming they deploy that A/C for the RECON mission. If the squadrons do not fly RECON missions throughout a deployment, then the commanders are not penalized when utilizing RFT when zero A/C on-hand can perform this capability. However, for this scenario the FMC is 0.00. This simplistic example illustrates how RFT can be a lower threshold for readiness in most cases, as the vast majority of situations will experience an RFT higher than the respective FMC.

A key distinction between the calculations of RFT and FMC involves the timeframes utilized. FMC is determined every reporting day regardless of whether any missions are scheduled to be flown that particular day, while RFT is only calculated when missions are required. Thus it is possible for FMC to exceed RFT during a month though this is unlikely (Buckley et al. 2010). Another simple example will clarify this point. Imagine that 10 A/C are in reporting status each day of a 30-day month. The first 24 days all 10 A/C are FMC, but the last six days each of the 10 suffer a RECON failure. Hence, there are 240 A/C-days of FMC and 60 A/C-days that are not FMC and the FMC fraction is 240/300 = 0.80. Unfortunately for the squadron, the first 24 days required no RECON missions while each of the last six days the RECON requirement was five. The RFT fraction for the month is calculated as 0/30 = 0.00 which is lower than the FMC for the month.

2. Readiness Impact of APN-6 Funding Levels

The Logistics Management Institute (LMI) conducted two relevant studies: the first treats FMC goals in aviation repairable allowancing (Buckley et al. 2010), and the second (summarized in this section), studies the readiness impacts of funding levels (Buckley et al. 2011).

As funding for Department of Defense (DoD) appropriations has received more visibility, APN-6 (spares for Aircraft Procurement, Navy) obligations have trended downward in relation to recommended levels even as mission requirements have increased. The annual APN-6 requirement (for all naval Type/Model/Series - T/M/S) increased from an average of $949M in the five years preceding the 9/11 terrorist attacks to $1.38B in the 10 years since. However, actual APN-6 funding averaged 88% of the

stated requirement prior to 9/11 and 84% since, thus appropriated funding regularly falls short of requirements. Since 9/11 annual aviation spares funding averaged $1.16B and the F/A-18E/F Super Hornet accounts for 20% of this total. An available supply of aviation spares is necessary to provide a buffer for part failures on A/C; the supply system in conjunction with the maintainers and the Mean Time Between Failures (MTBFs) determine the readiness of A/C. As the Average Customer Wait Time (ACWT) decreases due to having more spares on-hand, readiness should improve. Thus adequate spares funded should increase FMC and related readiness measures. Traditionally the Navy has utilized the ARROWs model to project APN-6 requirements; however, the Navy is transitioning towards SPO, a Commercial Off-the-Shelf (COTS) tool that provides a solution satisfying standards at a projected savings of 3%.

LMI found that since 2006 the overall T/M/S FMC rates have been declining. If the APN-6 account is funded at 75% of its requirements, the overall FMC standard of 0.56 (for all T/M/S) will likely be met. When all T/M/S are aggregated, it appears that as funding increases FMC increases until requirements are funded at the 84% level. FMC then is unaffected by increases in funding percentage until APN-6 is funded at 95% of requirements. Therefore additional funding beyond 84% does not generate an adequate return on investment. However, LMI addresses several issues which limit the applicability of its results. Non-deployed sites will likely exceed their FMC standards while deployed squadrons will fall short due to flight hour demands and shipping times. In addition, actual APN-6 funding execution is not broken down by individual T/M/S (unlike the requirements process); therefore it is unlikely each T/M/S will achieve its standard even though the aggregate standard is met.

LMI presents a solid description of the funding process regarding the Navy Working Capital Fund (NWCF) and APN-6. Due to extended lead times, requirements for aviation spares are determined three years prior to the date they are needed. The NWCF places orders 18 to 36 months in advance from the Original Equipment Manufacturer (OEM) and the spares are received at the wholesale level and paid for with NWCF dollars. When these parts are delivered to the squadrons, APN-6 funding reimburses the NWCF. Since NWCF expenditures in anticipation of FY15's

requirements are limited to the APN-6 level authorized for FY15 while NWCF requisitions parts up to three years prior to FY15, any increase in actual FY15 commitments may result in shortfalls. Similarly Congressional delays in APN-6 funding projections lead to greater spares availability uncertainty since the spares are ordered via the NWCF years in advance. Of note, spares purchased by a squadron in FY15 may be required to replace a failed part years later. Hence a reduction in the APN-6 account for FY15 may not impact readiness for FY15: the effects could be felt in following years.

3. Assessing the Use of Full Mission Capability Goals in Aviation Repairable Allowancing

The second LMI study of note is summarized below (Buckley et al. 2010). This LMI report revealed a very small correlation between RFT and FMC for the Super Hornet during deployment. There were more significant correlations for the E-2C Hawkeye, F/A-18C Hornet, and MH-60R Seahawk but these correlations could not be considered strong.

The LMI study also analyzed the impacts FMC standards had on aviation spares funding as determined using the ARROWs model. With this model, funding for all T/M/S A/C embarked on an aircraft carrier is more sensitive to an increase in the FMC requirement than a decrease, thus the model predicts if one desired to implement higher FMC standards the costs would increase significantly. For the Super Hornet single seat (F/A-18E) and tandem seat (F/A-18F) versions, the impacts are moderate compared with the Hawkeye and the SH-60F Seahawk (Table 1). As an example, an increase from the current Super Hornet overall standard of an FMC of 0.63 to 0.68 would raise spares costs by 3.8% for the F version while an increase to 0.78 results in a 15.3% cost increase. Deployed Marine units displayed the largest sensitivity to an FMC standard increase while shore sites were less sensitive than deployed Navy CVWs. Instead of increasing the APN-6 funding, LMI suggests FMC increases may be better accomplished through quicker turnaround times for repairs as LMI found a higher correlation between FMC and downed systems due to maintenance than supply. However, LMI concludes increases in APN-6 funding positively affect the FMC of deployed units.

	FMC -15%	FMC -10%	FMC -5%	Baseline	FMC +5%	FMC +10%	FMC +15%
E-2C	-11.0%	-9.5%	-5.6%	0.0%	7.9%	24.7%	24.9%
SH-60F	-9.7%	-7.3%	-3.0%	0.0%	5.4%	11.0%	19.0%
F-18F	-9.2%	-6.8%	-3.7%	0.0%	3.8%	9.5%	15.3%
F-18E	-9.1%	-6.4%	-3.4%	0.0%	3.6%	8.5%	14.7%

Table 1. Change in funding requirements vs. FMC Predicted Using ARROWs model

B. FOCUS AND ORGANIZATION OF THE THESIS

Beyond the 2010 LMI study that revealed a very small correlation between RFT and FMC for the Super Hornet during deployment, to the knowledge of Naval Supply Systems Command (NAVSUP) Weapons Systems Support (WSS), no studies have thoroughly analyzed the relationships between RFT, FMC, and other factors. This thesis will address this gap by conducting an exploratory data analysis on more than five years of data (March 2007 through June 2012) from F/A-18E/F Super Hornet squadrons based at Naval Air Station Oceana (Virginia Beach, VA). These Carrier Air Wings (CVWs) and their squadrons are:

- CVW-1 (Enterprise): VFA-211, VFA-136, VFA-11
- CVW-3 (Truman): VFA-105, VFA-32
- CVW-7 (Eisenhower): VFA-103, VFA-143
- CVW-8 (Bush): VFA-213, VFA-31
- CVW-17 (Vinson): VFA-81 (joins east coast December 2008 although Vinson is home-ported in San Diego)

Chapter II addresses data collection while defining the variables used in this study. Chapter III is dedicated exclusively to the relationship between FMC and RFT including how they change over phases. Chapter IV provides exploratory analysis regarding trends within the FRTP for the remaining variables. Chapter V provides a mixture model with two components: a logistic regression model followed by a multiple regression utilizing those observations where RFT was less than 1.00. These models illustrate the importance of variables on RFT. Chapter VI provides the conclusions and recommendations

II. DATA COLLECTION

A. METHODOLOGY

This thesis analyzes more than five years of data (March 2007 through June 2012) from F/A-18E/F Super Hornet squadrons based at NAS Oceana in Virginia Beach, VA. Squadrons were followed through all phases of the workup training cycle including deployment. VFA-106 is not included in this analysis since VFA-106 is utilized to train pilots in preparation for joining the Fleet. NAS Oceana supported CVWs 1, 3, 7, and 8 during all 64 months in the timeline; while CVW-17 arrived December 2008 for a total of 43 months receiving support from Oceana. Thus, there are 299 potential wing/month combinations within this dataset and each wing/month combination is treated as an observation. Hence, RFT and FMC metrics are aggregated for each wing and for each month as defined explicitly in the next section. While the background in Chapter I presented a theoretical example where RFT is less than FMC, this dataset contained six observations where RFT was below FMC without a reasonable explanation beyond errors in the respective values reported. As a result, these six anomalies were removed from the dataset and 293 observations remained for the empirical analysis. The removed observations include CVW-1 May 2008, CVW-3 March 2007, and CVW-17 October 2009 through January 2010. However, all 299 observations are displayed in plots depicting trends for the benefit of visual continuity.

Finally, correlation strengths are reported consistent with the definitions used in the 2011 LMI study regarding the readiness impacts of aviation spares funding levels (Buckley et al. 2011) where:

0.20 - 0.40	low correlation; definite but small relationship,
0.40 - 0.70	moderate correlation; substantial relationship,
0.70 - 0.90	high correlation; marked relationship,
> 0.90	very high correlation; very dependable relationship.

Different organizations assign their own ranges and descriptions regarding the relative strengths of correlations, thus the correlation coefficients are included throughout this thesis and one can make their own conclusions regarding the relationships between the variables.

B. DEFINITIONS OF VARIABLES

We analyzed 11 variables and their relationships with RFT. These variables are defined in this section. The non-fractional variables in theory have unlimited ranges, however, we list the maximum values attained in the dataset (for example, it is fiscally and physically impossible to have infinity A/C within a deployed wing). Finally, the entitlements are located within the CNAF INSTRUCTION 3510 series, and they are driven by the number of A/C within the wing and the month/phase within the FRTP (CNAF INSTRUCTION 3510 series 2006).

- **FMC –** Material condition of an aircraft that can perform all of its missions (CNAF 4790.2B Appendix A 2012). An FMC percentage is reported daily as the number of FMC A/C divided by the number of A/C in reporting status. This thesis uses FMC as the monthly average of daily FMC rates. Range: 0.00 - 1.00.
- **RFT Entitled** - The average number of A/C required to perform assigned missions during the month. Range: 0 - 26.
- **RFT Actual** - The average number of A/C able to perform required missions during the month. Range: 0 - 26 with the stipulation RFT Actual cannot exceed RFT Entitled. This is to ensure a day where RFT < 1.00 is not offset by another day where RFT > 1.00. A month with a perfect RFT of 1.00 implies there are no days where RFT < 1.00, thus the wing was able to accomplish all required missions during a month. Otherwise a wing could achieve a 1.00 (or greater) RFT for a month yet fail to conduct a required mission. This thesis only incorporates RFT Actual indirectly within the calculation of RFT as a fraction: given RFT as a fraction and RFT Entitled, RFT Actual can be determined.
- **RFT –** The fraction of RFT Actual divided by RFT Entitled during a month. Range: 0.00 – 1.00. An A/C cannot be FMC without being RFT.
- **Ready Basic A/C (RBA)** - The minimum configuration required to conduct day or night Instrument Meteorological Conditions (IMC) flight operations with necessary communications, Identify Friend or Foe (IFF), navigation, flight and safety systems required by applicable Naval Air Training and Operating Procedures Standardization (NATOPS) and

Federal Aviation Administration (FAA) regulations (Current Readiness Handbook 2011). If an A/C can fly safely it is rated as RBA; otherwise it is not. An A/C cannot be FMC or RFT without being RBA. RBA is averaged over the month. Range: 0 – 32.

- **Wing** - All wings within the dataset employed one to three squadrons, and CVW-1 in particular carried one squadron (VFA-211) until July 2007 when VFA-136 was temporarily assigned for one month. In July 2008 CVW-1 permanently gained VFA-136 while gaining VFA-11 from CVW-3. The following is a list of squadrons supported by Oceana including the CVW each is assigned to as of June 2012.
  - **CVW-1 (Enterprise):** VFA-211, VFA-136, VFA-11
  - **CVW-3 (Truman):** VFA-105, VFA-32
  - **CVW-7 (Eisenhower**): VFA-103, VFA-143
  - **CVW-8 (Bush):** VFA-213, VFA-31
  - **CVW-17 (Vinson):** VFA-81 (joins east coast December 2008 although Vinson is home-ported in San Diego)
- **Phase** - The phase within the FRTP the wing predominantly operated in during a month. There are five phases: Maintenance, Basic, Intermediate, Sustainment, and Deployment.
  - **Maintenance –** Extensive maintenance conducted on A/C.
  - **Basic –** Training conducted at the unit level.
  - **Intermediate –** Integration with the aircraft carrier and the Carrier Strike Group (CSG); includes the Composite Training Unit Exercise (COMPTUEX) which is the major pre-deployment exercise for the battle group lasting three to four weeks.
  - **Sustainment –** Ready to deploy at short notice. This is the period immediately preceding and following the Deployment Phase, and the A/C must be maintained in condition to deploy if called upon.
  - **Deployment –** Extended underway with the CSG, usually of a period lasting at least six months. Readiness ideally reaches its apex and this is when the A/C provides a return on the taxpayers' dollars.
- **Flight Hours Accomplished (FHA)** - The number of flight hours flown during the month. Range: 0 - 3608.
- **Flight Line Assigned (FLA)** - The average number of A/C on the flight line in reporting status during the month. Range: 0 - 36.

- **FLA Entitled (or Standard)** - The minimum number of A/C required on the flight line in reporting status to support training/operations requirements (averaged over the month). Range: 0 - 36.
- **Assigned A/C** - The average number of A/C assigned to a wing during a month. Range: 0 - 37. FLA should always be no larger than Assigned A/C as not all Assigned A/C will be in reporting status due to extensive maintenance requirements.
- **Flight Hours (FHRS) Entitled (or Standard)** – The total flight hours required to accomplish the mission during the month. Range: 0 - 1469.
- **Training Flight Hours (TFHR) Entitled** - The flight hours required for training each month. Range: 0 - 1103. This is a subset of Flight Hours Entitled and represents the majority of the overall Flight Hours Entitled.

III. COMPARING RFT AND FMC

A. INTRODUCTION

For this thesis RFT and FMC are considered fractions (or percentages) where both variables range from 0.00 to 1.00. A day when requirements are exceeded cannot offset a day when RFT or FMC fell short of the mark. For example, if on one day nine of 10 required A/C can perform a specific mission while the following day 11 A/C can perform a specific mission when only 10 are required, the combined RFT for the two days is 0.95 rather than 1.00. Since RFT and FMC are measures of readiness, one could possibly assume a significant positive correlation between the two variables: as FMC increases, RFT should increase and vice versa.

Figure 1 displays a plot of RFT versus FMC including a loess smoother for the 293 wing/month observations (Cleveland, Grosse, and Shyu 1992). The minimum RFT was 0.72 thus the y-axis begins at 0.70 to present a clearer picture of the spread of RFT. Immediately one can observe a majority of RFT values are 1.00 (212 of 293 to be more precise) and RFT appears to increase with FMC with a leveling off in the interval from FMC = 0.5 to FMC = 0.65. This interval includes the FMC standards for the Super Hornet: 0.63 for deployed, 0.53 for non-deployed, and 0.58 overall. The trend within this interval combined with the finding that two of the five wings had a negative correlation between RFT and FMC (as FMC increased RFT decreased and vice versa) contribute to a correlation between FMC and RFT of 0.17. This demonstrates a small but indefinite positive linear relationship.

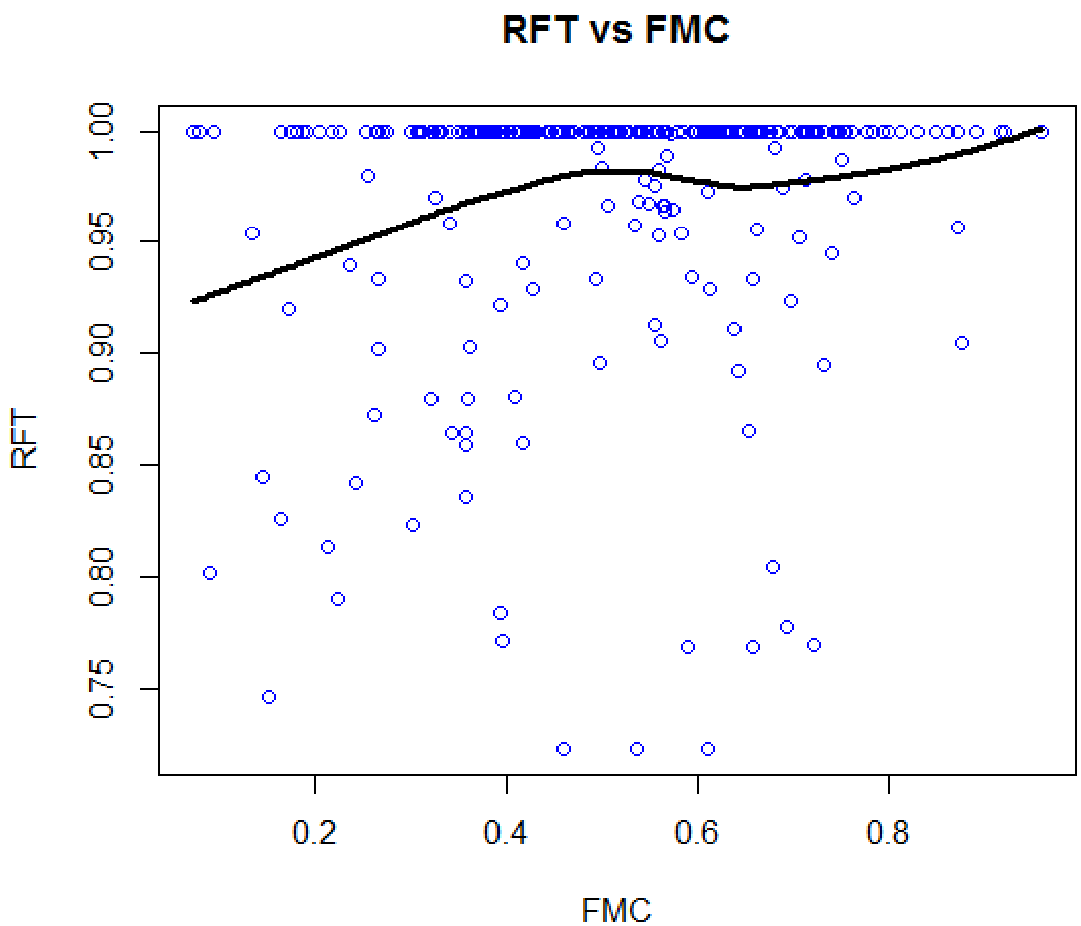

Figure 1. RFT vs. FMC for all 293 Observations including a Loess Smoother with Bandwidth = 0.7

Since 87 observations were less than 1.00, 27.6% failed to achieve the monthly RFT goal of 1.00. A perfect RFT within a month can only be accomplished if each and every day within that month achieved a perfect RFT, thus this finding implies that only during 27.6% of the wing/month combinations did a wing ever suffer a day where it was not 100% RFT during a month. RBA and FHA were the only variables with "definite but small relationships" (correlation coefficient 0.20 - 0.40) with respective correlations to RFT of 0.28 and 0.20. RFT includes RBA which may help explain the relationship between RFT and RBA. The only variable with a "definite but small relationship" with FMC was RBA, with a correlation of 0.25.

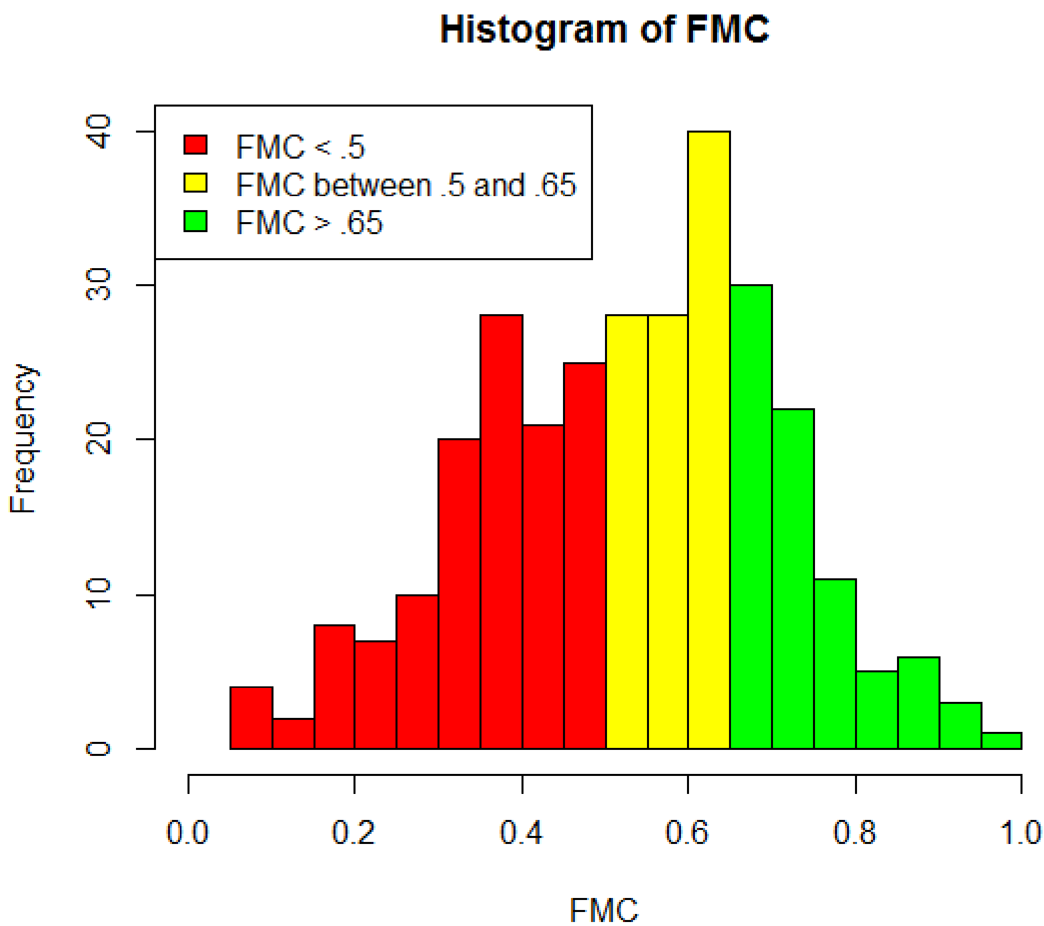

Figure 2. Histogram of the FMC Values for 293 Wing/Months

Figure 2 shows the FMC distribution for the 293 wing/month combinations (Venables and Ripley 2002). While 72.4% of the RFT values are 1.00, the distribution for FMC is more evenly distributed about the mean (0.52) and the median (0.54). The FMC standards vary by T/M/S and by deployment status, and the overall monthly FMC standard for the Super Hornet is 0.58 while the deployed and non-deployed standards are 0.63 and 0.53 respectively (Buckley et al. 2011). FMC ranged from 0.07 to 0.96.

	Deployed	Non-Deployed	
Met FMC Standard	28 (37.8%)	97 (44.3%)	125
Failed to Meet FMC Standard	46 (62.2%)	122 (55.7%)	168
	74	219	293

Table 2. Wing/Months where FMC Standards are Met by Deployment Status

Table 2 provides a summary of the number of wing/month observations where FMC standards are met by a wing's deployment status. Out of 74 months where a wing was deployed, 28 met the FMC standard of 0.63 (37.8%) while the 219 months where a wing was not deployed saw 97 meet the standard of 0.53 (44.3%). 42.7% of all observations met the FMC standard compared to 72.4% that achieved the RFT goal of 1.00. Tables 3 and 4 present the breakdown of RFT success by deployment status for those observations where the FMC standards were and were not achieved respectively. Of the 28 during deployment where the FMC standard was met, 22 (78.6%) achieved a perfect RFT, while 68 of 97 (70.1%) non-deployed satisfactory FMC rates achieved an RFT of 1.00. 72.0% of all observations achieving the FMC standard also met the RFT goal. Of the 46 during deployment where the FMC standard was not met, 38 (82.6%) earned a perfect RFT, while 84 of 122 (68.9%) non-deployed unsatisfactory FMC rates attained a perfect RFT.

	Deployed	Non-Deployed	
Met RFT Goal	22 (78.6%)	68 (70.1%)	90
Failed to Meet RFT Goal	6 (21.4%)	29 (29.9%)	35
	28	97	125

Table 3. Numbers of Wing/Months by Deployment Status and whether RFT Goals were Achieved for Observations where FMC Standards were Met

	Deployed	Non-Deployed	
Met RFT Goal	38 (82.6%)	84 (68.9%)	122
Failed to Meet RFT Goal	8 (17.4%)	38 (31.1%)	46
	46	122	168

Table 4. Numbers of Wing/Months by Deployment Status and whether RFT Goals were Achieved for Observations where FMC Standards were not Met

Using Fisher's Exact Test for count data based on 2 x 2 contingency tables (Fisher 1925), the fractions of wing/months meeting the standards or goals were not statistically different (at a significance level of 5%, two-sided) depending upon deployment status for any of the three tables. Thus being deployed neither affected the wings' abilities to achieve FMC standards nor did being deployed aid wings in meeting RFT goals for FMC success or failure.

Table 5 provides a summary of the number of wing/month observations where RFT goals are met by a wing's deployment status. Out of 74 months where a wing was deployed, 60 met the RFT goal (81.8%) while the 219 months where a wing was not deployed saw 152 meet the goal (69.4%). Fisher's Test also concluded at a significance level of 5% that the deployment status did not impact a wing's ability to record a perfect RFT.

	Deployed	Non-Deployed	
Met RFT Goal	60 (81.8%)	152 (69.4%)	212
Failed to Meet RFT Goal	14 (18.2%)	67 (30.6%)	81
	74	219	293

Table 5. Wing/Months where RFT Goals are Met by Deployment Status

The mean FMC during deployed months was 0.61 with a standard deviation of 0.13 while the mean for non-deployed months was 0.49 with a standard deviation of 0.18.

This shows that on average wings are barely missing the FMC standards, but the majority of observations (72.4%) achieve an RFT of 1.00. Thus depending upon which metric is used, a dataset can either show via RFT that the squadrons are being supported reasonably well or it can be concluded via FMC that the squadrons are not receiving enough support to achieve readiness standards. A further look into the data reveals that of the 14 observations where FMC was below 0.20, eight achieved a perfect RFT. Nine of these 14 observations were in the Maintenance Phase, two each in Basic and Intermediate, and the other was in Sustainment. The RFT entitlements during these phases are not as high as in Deployed, thus a smaller number of actual RFT A/C is required to achieve a perfect RFT fraction of 1.00.

Clearly the relationship between RFT and FMC is weak. Given a value of FMC without any additional information, one cannot predict RFT to a reasonable degree of certainty other than by guessing RFT = 1.00 every time. The exception to this is when FMC is abnormally high there is a good chance RFT = 1.00; however, only 13 of 293 observations achieved an FMC as high as 0.80 (two of which had RFT < 1.00). For the 87 instances when RFT < 1.00 the average RFT was 0.90, thus when units fall short of the RFT goal they are not falling short by a large margin.

B. ANALYSIS OF RFT VERSUS FMC FOR EACH WING

In this section, we consider RFT and FMC separately for each wing. Detailed plots of FMC and RFT by month and phase within the FRTP illustrate how FMC paints a much clearer picture of wing readiness than does RFT.

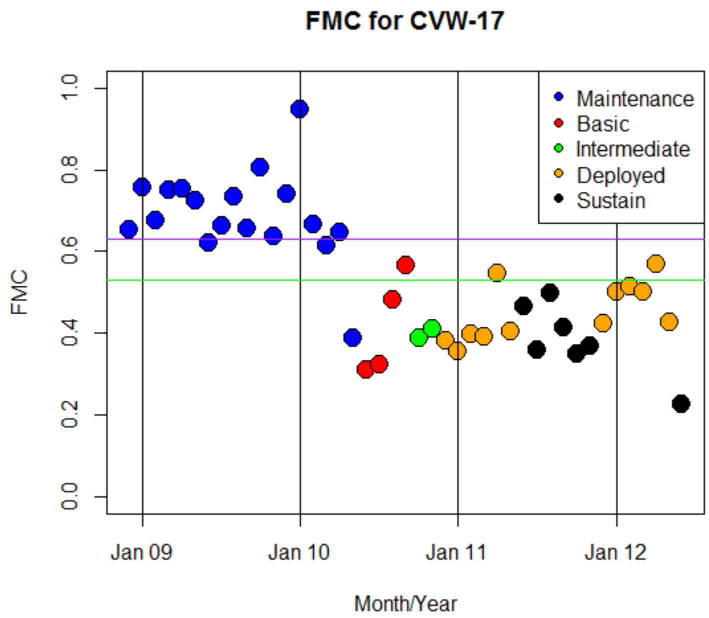

Figure 3. FMC over Time for CVW-17, with the Deployed FMC Standard 0.63 (purple line) and the Non-deployed Standard 0.53 (green line)

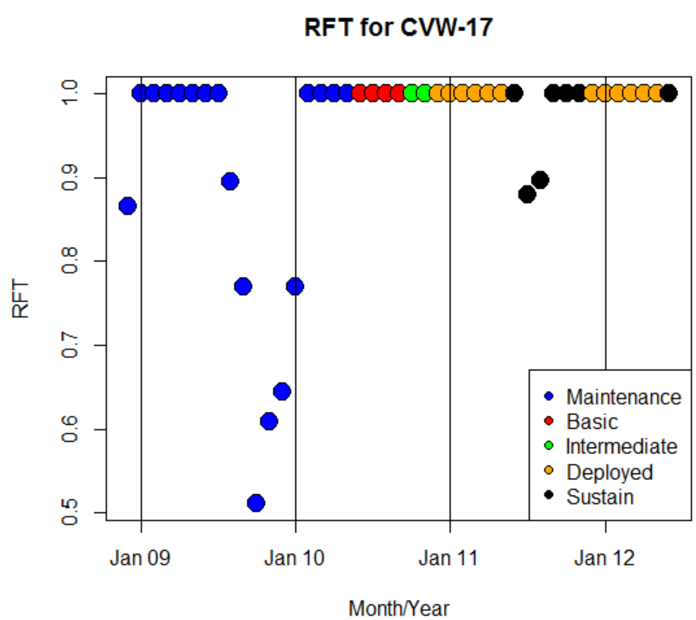

Figure 4. RFT over Time for CVW-17

Figures 3 and 4 show FMC and RFT for CVW-17 from December 2008 through June 2012 (CVW-17 transitioned to the east coast December 2008). Note the months from October 2009 through January 2010 are removed from the dataset due to errors in reporting discovered when RFT was much less than FMC without a reasonable explanation. Even when one removes these observations from Figures 3 and 4, it is clear Figure 3 paints a more detailed and quite a different picture of readiness than does RFT in Figure 4.

During the first year-plus, CVW-17 was in the Maintenance Phase and it consistently met its non-deployed FMC standard of 0.53 (the green horizontal line) until just prior to its transition to the Basic Phase where its FMC fell off dramatically and stayed low (and below standard) the remainder of the period with the exception of September 2010 - the last month within the Basic Phase. CVW-17 never achieved the FMC standard of 0.63 (the purple horizontal line) during deployment. Contrast this with the plot of CVW-17's RFT values: RFT was the lowest during the Maintenance Phase and the only other phase with RFT < 1.00 is the Sustainment Phase prior to deployment. Thus in FMC terms the Maintenance Phase generated the best results but in terms of RFT the Maintenance Phase produced the worst results. For CVW-17, RFT used as a standard for readiness does not present the same picture as FMC.

CVW-17			
	Total	% FMC Met Standard	% RFT Met Goal
Maintenance	14	93%	79%
Basic	4	25%	100%
Intermediate	2	0%	100%
Sustainment	7	0%	71%
Deployment	12	0%	100%
Total	39	36%	87%

Table 6. % of Observations Meeting FMC and RFT Goals for CVW-17

Table 6 presents the percentages of months where CVW-17 meets its FMC and RFT goals by phase. During the Intermediate and Deployment Phases there were no months where the respective FMC standards were achieved, yet every month attained the

RFT goal. Overall more than twice as many months met the RFT goal as compared to FMC. Thanks largely due to the success during the Maintenance Phase, Fisher's Test concludes the FMC results are statistically significant at the level of 5% – there is a difference in achieving the FMC standards between the phases. However, there is not a statistically significant difference in the achievement of the RFT goal between phases.

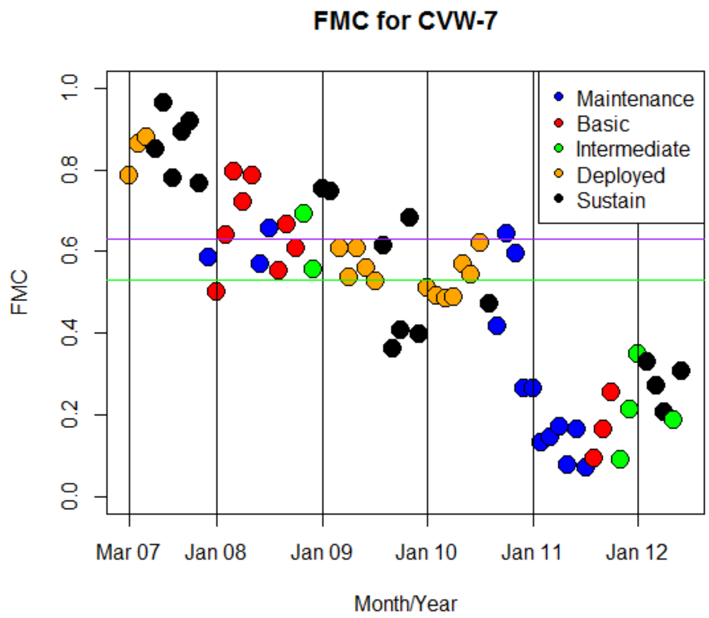

Figure 5. FMC over Time for CVW-7, with the Deployed FMC Standard 0.63 (purple line) and the Non-deployed Standard 0.53 (green line)

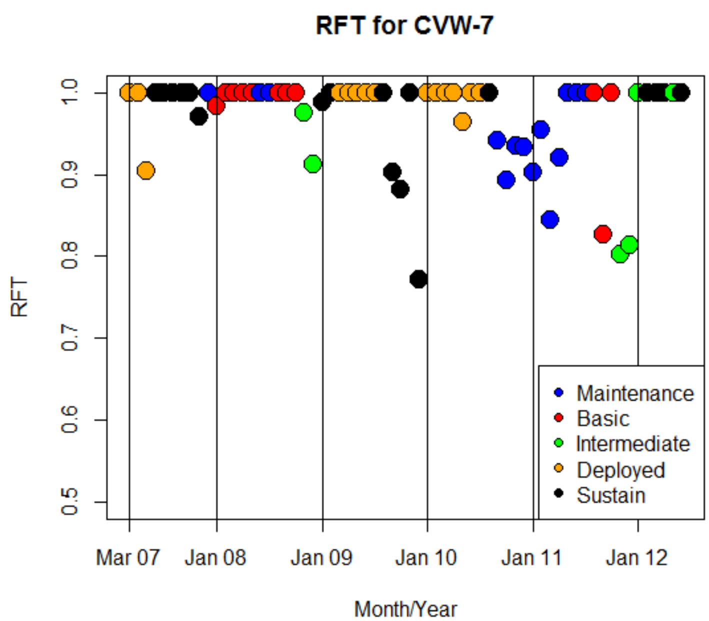

Figure 6. RFT over Time for CVW-7

CVW-7 contained no observations omitted due to reporting anomalies. Figure 5 shows that FMC rates declined consistently throughout the period until mid-2011, regardless of the phase. FMC was above standard (with the exception of January 2008) on all occasions until the first month of the second deployment, then FMC only reached its standard during four subsequent months. CVW-7 went on back-to-back deployments at the beginning of 2009 and 2010 and the Eisenhower entered a yard period at the end of 2010 which may explain some of this trend. In Figure 6, RFT does not begin to show relative decline until the end of the 2010 deployment. Notice how one can glean a lot more about readiness trends from the FMC plot in Figure 5 compared with the RFT in Figure 6.

CVW-7			
	Total	% FMC Met Standard	% RFT Met Goal
Maintenance	14	36%	43%
Basic	11	64%	82%
Intermediate	6	33%	33%
Sustainment	18	56%	72%
Deployment	15	20%	87%
Total	64	42%	67%

Table 7. % of Observations Meeting FMC and RFT Goals for CVW-7

From Table 7, FMC fared the worst during Deployment while RFT was at its highest. Overall the FMC standard was achieved less than half the months whereas RFT was achieved two of every three months. With Fisher's Test at a 5% level of significance, there is a difference in the proportion of wing/month observations achieving the RFT goal between the phases. However, there is not a statistically significant difference in the achievement of the FMC standard between phases.

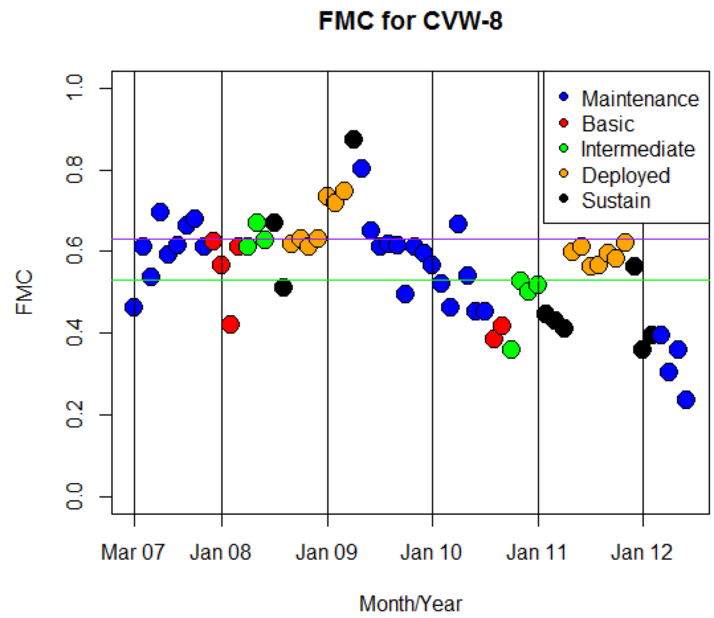

Figure 7. FMC over Time for CVW-8, with the Deployed FMC Standard 0.63 (purple line) and the Non-deployed Standard 0.53 (green line)

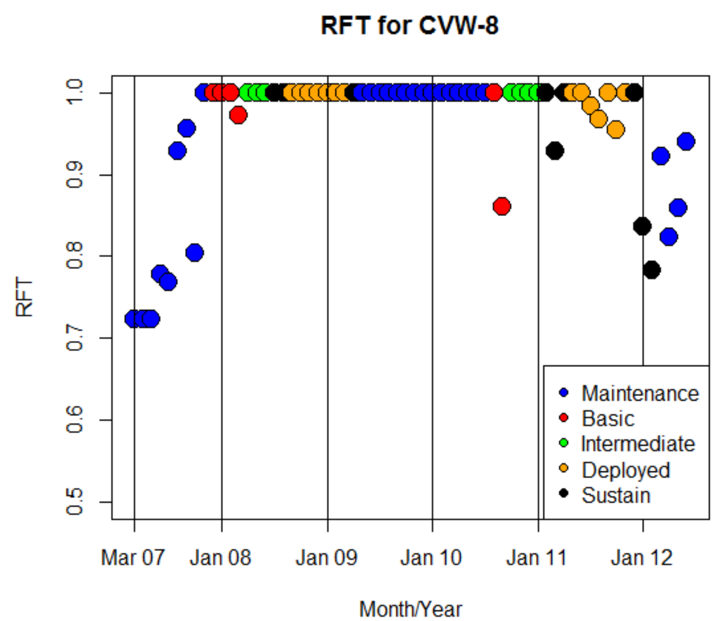

Figure 8. RFT over Time for CVW-8

CVW-8 contained no observations omitted due to reporting anomalies. From Figure 7, CVW-8's FMC rates appear to be more cyclical with a period of nearly three years. 2007-2009 shows FMC rates above standard most of the time while 2010-2012 shows FMC rates below standard with the exception of four months. In addition to the cyclical trend, it appears FMC is improving during the lead-up to deployment while it is declining post-deployment and this concurs with readiness trends one would prefer to see during the inter-deployment cycle. The RFT plot in Figure 8 shows RFT rates increasing through the end of 2007, spending the next three and a half years with a perfect RFT with the exception of three months, then RFT < 1.00 the remainder of the time with the exception of three months. So although the FMC standard is met for most of 2007, the RFT goal is only achieved beginning in November 2007. While FMC begins to decline mid-2009, RFT stays perfect until September 2010. The trends among the phases are also reflected in Table 8. Fisher's Test concludes there was not a statistically significant difference (at a 5% level of significance) in the achievement of either the FMC standards or the RFT goals between the phases for CVW-8.

CVW-8			
	Total	% FMC Met Standard	% RFT Met Goal
Maintenance	28	64%	57%
Basic	6	50%	67%
Intermediate	7	43%	100%
Sustainment	9	33%	67%
Deployment	14	36%	79%
Total	64	50%	69%

Table 8. % of Observations Meeting FMC and RFT Goals for CVW-8

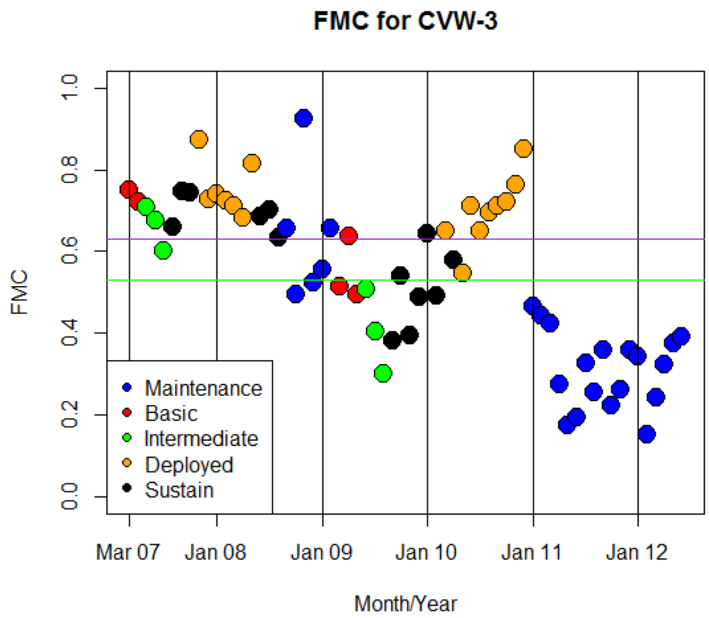

Figure 9. FMC over Time for CVW-3, with the Deployed FMC Standard 0.63 (purple line) and the Non-deployed Standard 0.53 (green line)

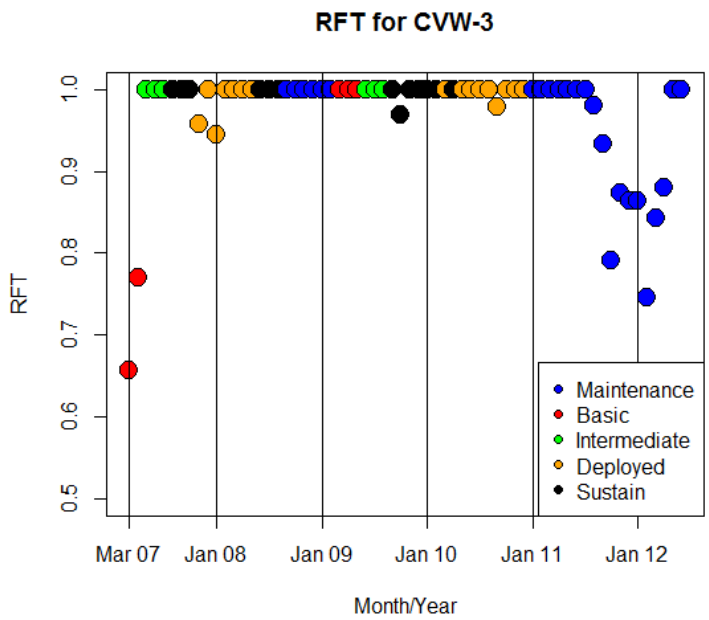

Figure 10. RFT over Time for CVW-3

CVW-3 contained one observation (March 2007) omitted due to reporting anomalies. CVW-3's FMC plot in Figure 9 trends upward leading up to deployment and falls off after deployment. Further, there was only one month (May 2010) encompassing both deployments where FMC fell below standard. Following the second deployment CVW-3 entered the Maintenance Phase where none of the months achieved the FMC standard of 0.53, but this effect was offset by the success achieved during the two deployments. The RFT plot in Figure 10 shows an abundance of months where RFT was not 1.00 after the second deployment which would appear to agree with the findings from the FMC plot. There is clearly a better readiness trend in the FMC plot compared with RFT.

CVW-3			
	Total	% FMC Met Standard	% RFT Met Goal
Maintenance	24	17%	63%
Basic	4	50%	75%
Intermediate	6	50%	100%
Sustainment	13	69%	92%
Deployment	16	94%	81%
Total	63	52%	78%

Table 9. % of Observations Meeting FMC and RFT Goals for CVW-3

From Table 9, CVW-3 only achieved the FMC standard 17% of the time while in the Maintenance Phase, yet the RFT goal was met at a rate of 63%. Fisher's Test shows, at a 5% level of significance, there is a difference in achieving the FMC standards between the phases. However, there is not a statistically significant difference in the achievement of the RFT goal between phases.

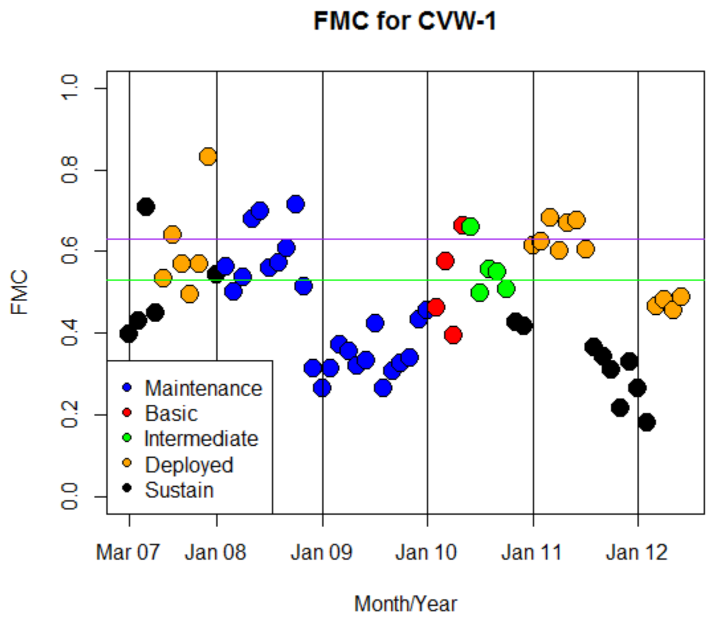

Figure 11. FMC over Time for CVW-1, with the Deployed FMC Standard 0.63 (purple line) and the Non-deployed Standard 0.53 (green line)

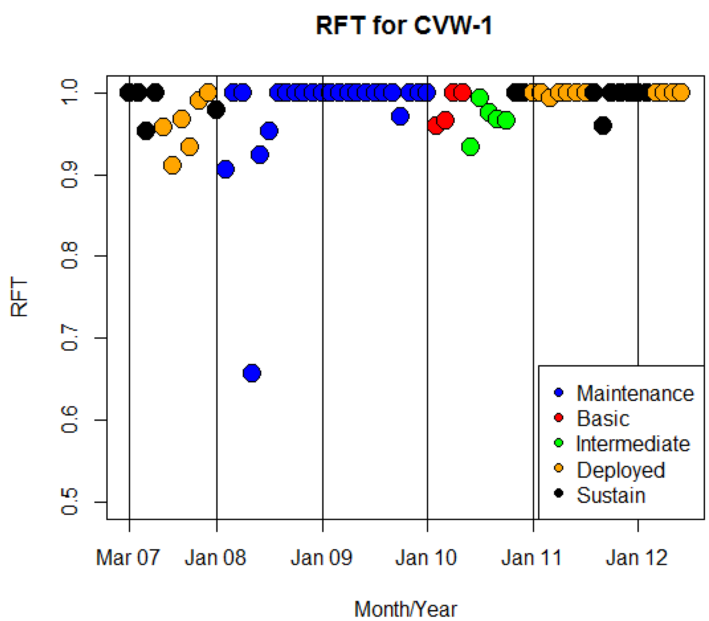

Figure 12. RFT over Time for CVW-1

CVW-1 contained one observation (May 2008) omitted due to reporting anomalies. CVW-1's FMC rates from Figure 11 appear to be trending upward leading up to deployment while falling off post-deployment; however, the majority of the FMCs falls below standard. Contrast this with CVW-1's RFT plot in Figure 12: after removing May 2008, there are not any observations falling below an RFT of 0.90 whereas every other wing had several RFTs < 0.90. Judging by FMC standards CVW-1 is failing to meet the mark, but hypothetically if the basis is RFT < 0.90 (the actual goal is 1.00) then CVW-1 is performing better than the other wings.

CVW-1			
	Total	% FMC Met Standard	% RFT Met Goal
Maintenance	23	30%	78%
Basic	4	50%	50%
Intermediate	5	60%	0%
Sustainment	14	14%	79%
Deployment	17	29%	65%
Total	63	30%	67%

Table 10. % of Observations Meeting FMC and RFT Goals for CVW-1

From Table 10, although there were only five months in the Intermediate Phase, FMC performed the best within the Intermediate Phase but this is also where RFT fared the worst. Likewise the Sustainment Phase is where FMC performed the worst while RFT performed the best. CVW-1 met its RFT goal twice as often as its FMC standard. Fisher's Test concludes the RFT results are statistically significant at the level of 5% – there is a difference in achieving the RFT goal between the phases. However, there is not a statistically significant difference in the achievement of the FMC standard between phases.

C. COMBINED RFT AND FMC PERFORMANCE RATES

% Met FMC					
	CVW-1	CVW-3	CVW-7	CVW-8	CVW-17
Maintenance	30%	17%	36%	64%	93%
Basic	50%	50%	64%	50%	25%
Intermediate	60%	50%	33%	43%	0%
Sustainment	14%	69%	56%	33%	0%
Deployment	29%	94%	20%	36%	0%

Table 11. % of Months Meeting FMC Standards for Each Wing by Phase

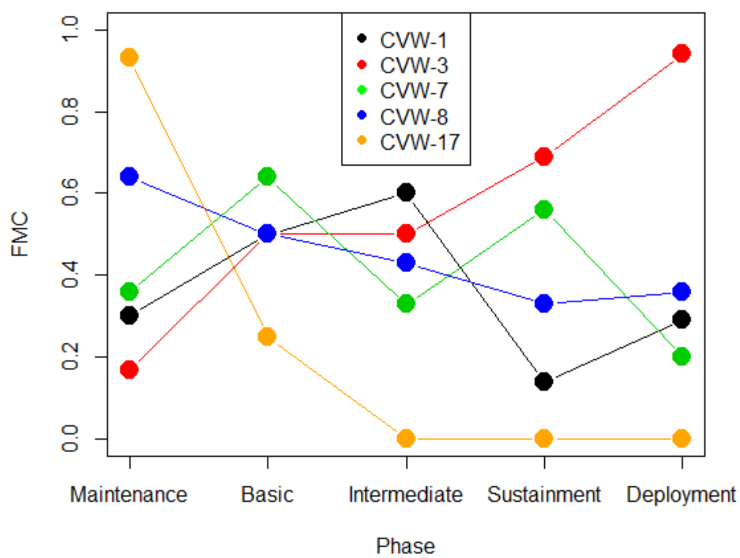

Figure 13. Line Chart for % of Months Meeting FMC Standards for Each Wing by Phase

Table 11 gives the percentage of months the FMC standard is achieved for each wing broken down by phase. The percentages of Table 11 are depicted with a line chart in Figure 13. CVW-17 performed better than the other wings during the Maintenance Phase while performing much worse than the other wings in the other phases. There are no rows or columns which exhibit dominant characteristics: no wings performed better than another wing in all phases and no phase had higher results than another phase for all wings.

% Met RFT					
	CVW-1	CVW-3	CVW-7	CVW-8	CVW-17
Maintenance	78%	63%	43%	57%	79%
Basic	50%	75%	82%	67%	100%
Intermediate	0%	100%	33%	100%	100%
Sustainment	79%	92%	72%	67%	71%
Deployment	65%	81%	87%	79%	100%

Table 12. % of Months Meeting RFT Goals for Each Wing by Phase

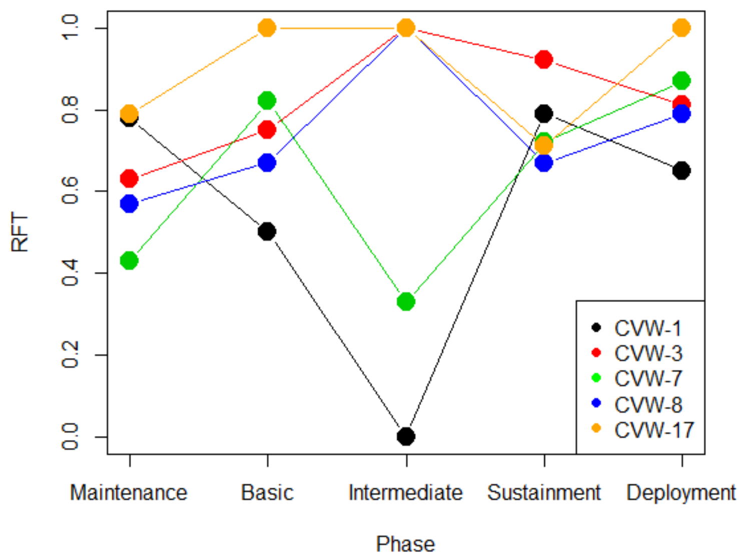

Figure 14. Line Chart for % of Months Meeting RFT Goals for Each Wing by Phase

Contrast the FMC findings with Table 12 and Figure 14 which displays the percentage of months where RFT = 1.00 for each wing by phase. While CVW-17 did accomplish its RFT goals at a higher rate than the other wings during the Maintenance Phase, the margin was not as large as it was for FMC. CVW-3 was in the middle of the pack during all phases except Intermediate and Sustainment where it led the way. CVW-3 and CVW-17 dominated CVW-8 in achieving the RFT goal as both wings performed at least as well in all phases compared to CVW-8. However, the only phase where CVW-17 performed better than CVW-8 in FMC terms was the Maintenance Phase. Deployment dominated Basic as well with regards to RFT, but in FMC terms Basic fell short to Deployment only with CVW-3. With Fisher's Test, at a 5% significance level,

neither the phase nor the wing impacts the ability to achieve either the FMC standard or the RFT goal when evaluated as a whole. Knowing the wing (without the phase) does not help one predict whether FMC and/or RFT will be met, and knowing the phase (without the wing) is not helpful either. The combination of the wing and the phase is significant though for certain wings/phases as shown in the previous section. Specifically, phase mattered in FMC standards for CVW-3 and CVW-17 while phase was a factor in the achievement of a perfect monthly RFT for CVW-1 and CVW-7.

D. SUMMARY

There are three key observations from the comparisons of RFT and FMC:

1. Correlation between RFT and FMC is Small but Inconclusive

The correlation between RFT and FMC is 0.17, which demonstrates a small but inconclusive relationship. In fact both CVW-1 and CVW-17 had negative correlation coefficients: as RFT improved, FMC declined. RFT appears to increase with FMC with the exception of the interval from FMC = 0.5 to FMC = 0.65. This interval includes the FMC standards for the Super Hornet: 0.63 for deployed, 0.53 for non-deployed, and 0.58 overall. The decline in RFT over this interval is interesting and it prevents the correlation from being stronger. RFT and FMC are not measuring the same aspects of readiness.

2. RFT and FMC were not Systematically Affected by Wing or Phase

At a 5% significance level, neither the phase nor the wing showed systematic differences in the ability to achieve either the FMC standard or the RFT goal when evaluated as a whole. Knowing the wing (without the phase) does not help one predict whether FMC and/or RFT will be met, while knowing the phase (without the wing) is not helpful either. The combination of the wing and the phase is significant though for certain wings/phases. Specifically, phase mattered in the accomplishment of FMC for CVW-3 and CVW-17 while phase was a factor in the achievement of a perfect monthly RFT for CVW-1 and CVW-7.

3. FMC Presents a Clearer Readiness Trend than RFT

There are trends in overall readiness one can detect with the FMC plots that cannot be observed from RFT. For example, with FMC one can discern readiness increasing leading to deployment and then falling post-deployment. This difference in trends can be explained by the excess readiness available in RFT while there is no such thing as excess readiness for FMC. Imagine a scenario where there are 10 A/C that can perform all required missions, but the RFT Entitled is five. Only five of the A/C will contribute towards the RFT fraction since by definition RFT Actual cannot exceed RFT Entitled. In contrast, all 10 A/C contribute to the FMC fraction. Thus when utilized as fractions, FMC provides a clearer picture of readiness than RFT.

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IV. TYPICAL TRENDS WITHIN THE INTER-DEPLOYMENT CYCLE

A. INTRODUCTION

This chapter begins by describing the phases within the inter-deployment cycle in more detail. In the aim of providing visual clarity of trends among phases, scatterplots of each variable considered within this analysis are also provided. These scatterplots illustrate the relationships between variables and show how different variables change during the course of the 27-month FRTP. Explanations for the trends are also suggested. Further, plots of RFT Actual and RFT are provided for comparison of the two, although RFT Actual is not utilized in any models to predict RFT in this thesis.

B. PHASES WITHIN THE FRTP

The FRTP contains five distinct phases: Maintenance, Basic, Intermediate, Sustainment, and Deployment. Each phase corresponds to specific readiness, maintenance, and performance expectations with the underlying goal of being as prepared as possible to conduct operational missions during scheduled deployments and unscheduled contingencies. Different air wings are in different phases of the FRTP at any given moment, and the FRTP is designed to last 27 months. During the Maintenance Phase extensive maintenance is performed to extend the lifetime of the A/C. Training at the unit level is conducted during the Basic Phase, while the wings integrate with their aircraft carriers and CSGs during the Intermediate Phase. This is also the phase where the major pre-deployment exercise for the battle group - COMPTUEX – is conducted. A wing is ready to deploy at short notice during the Sustainment Phase and this immediately precedes and follows the Deployment. The taxpayers receive their returns on investment during the Deployment Phase when the wing and battle group is typically underway at least six months. This is when readiness is desired to be at its apex (Sanford 2007).

Within this dataset of 293 wing/month observations, on average wings spent nine months in the Maintenance Phase and all wings entered the Basic Phase from

Maintenance. Wings spent three months in the Basic Phase and 89% transitioned to the Intermediate Phase from Basic. Wings spent three months in the Intermediate Phase and 89% transitioned to the Sustainment Phase. Wings spent three months in the Sustainment Phase and they either transitioned to Deployment or Maintenance depending upon whether they were ramping up for deployment or returning home. Wings spent six months in Deployment and 91% entered the Sustainment Phase.

While the FRTP is designed to last 27 months, operational requirements and world events often require modifications to this schedule. For example, CVW-7 embarked on back-to-back deployments 2009 and 2010 and as a result the COMPTUEX took place during the Sustainment Phase instead of Intermediate. This chapter provides plots of variables along the FRTP with color-coded phases as introduced in Chapter III: blue – Maintenance; red – Basic; green – Intermediate; black – Sustainment; and gold – Deployment. This technique provides a visual reference to help one grasp the ebbs and flows during the inter-deployment cycle.

C. RFT AND RFT ACTUAL

Of the variables considered in this thesis, RFT is most strongly related with RFT Actual – the average number of A/C designated RFT during a month – with a correlation coefficient of 0.28 (a low correlation; definite but small relationship). A 1.00 value indicates a perfect positive linear relationship (as one variable goes up, the other variable goes up by a constant proportion); while a -1.00 value indicates a perfect negative linear relationship (as one variable goes up, the other variable goes down by a constant proportion). A 0.00 coefficient indicates no linear relationship whatsoever. The 2011 LMI study regarding the readiness impacts of aviation spares funding levels will be used as a guide to assess correlation strength as was done in Chapter III (Buckley et al. 2011). Since RFT is calculated as RFT Actual divided by RFT Entitled and the entitlement is more informative than the actual, RFT Actual will not be considered while retaining RFT Entitled.

As the daily average of A/C designated RFT increases (RFT Actual), an increase in the fraction of RFT is expected. If the RFT Entitled was constant for all 293

observations, the correlation between RFT and RFT Actual would be 1.00. However, the entitlement is affected by the month/phase and the number of A/C in the wing and these effects substantially reduce the correlation. Figure 15 illustrates the weakness of the relationship between RFT and RFT Actual for CVW-3, whose correlation coefficient is 0.31. RFT Actual is cyclical with peaks during Deployment and valleys during Maintenance. The months immediately prior to and following Deployment are Pre-Overseas Movement and Post-Overseas Movement (POM) periods of approximately one month allowing for personnel to go on leave: RFT Actual declines accordingly.

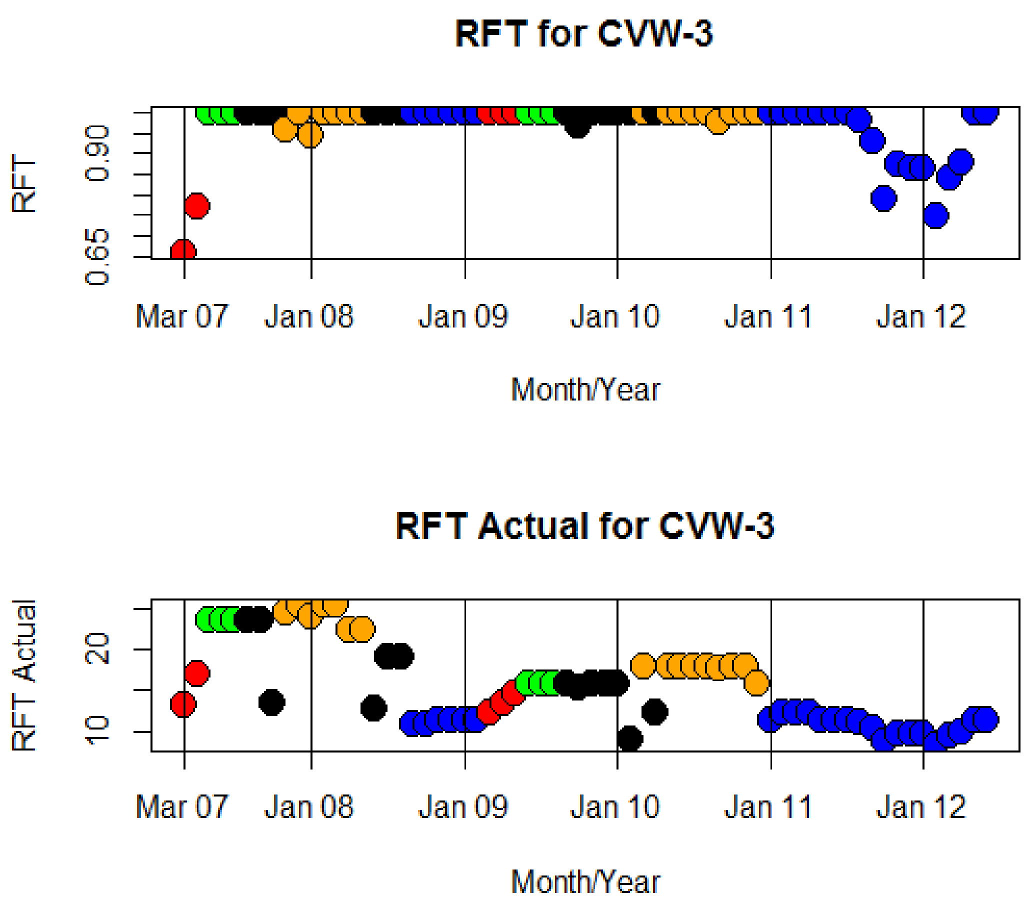
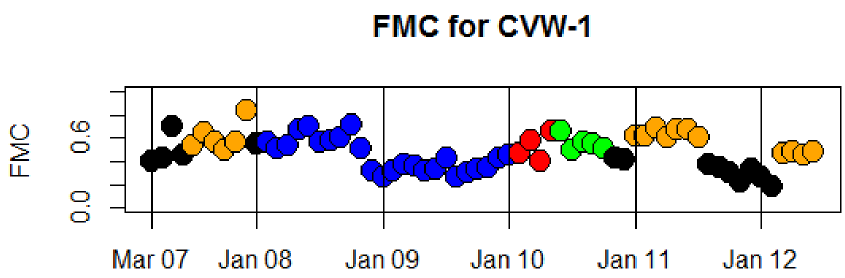
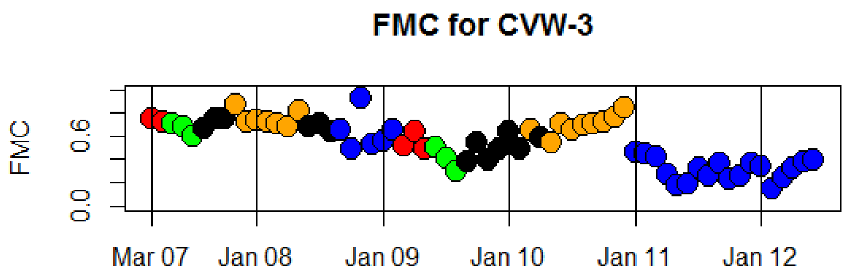


Figure 15. RFT and RFT Actual for CVW-3 (Correlation Coefficient = 0.31)

D. FMC AND RBA

FMC is most strongly related with RBA - a correlation coefficient of 0.25 (a low correlation; definite but small relationship). All other variables have inconclusive relationships with FMC (correlation coefficient < 0.20). An A/C cannot attain FMC without achieving RBA status. While time is not considered a regressor in this thesis, FMC and the date (month/year) have a moderate negative correlation of -0.60. There is a substantial decrease in FMC over time. All five wings analyzed had statistically significant differences in FMC accomplishment by year. This finding supports the results from LMI's September 2011 study concluding a negative trend in FMC values for overall T/M/S A/C since 2006 (Buckley et al. 2011). Figure 16 presents the plots of FMC for all wings over time. Note CVW-17 did not transition to the east coast until December 2008.


FMC for CVW-1
FMC
0.0
0.6
Mar 07
Jan 08
Jan 09
Jan 10
Jan 11
Jan 12


FMC for CVW-3
FMC
0.0
0.6
Mar 07
Jan 08
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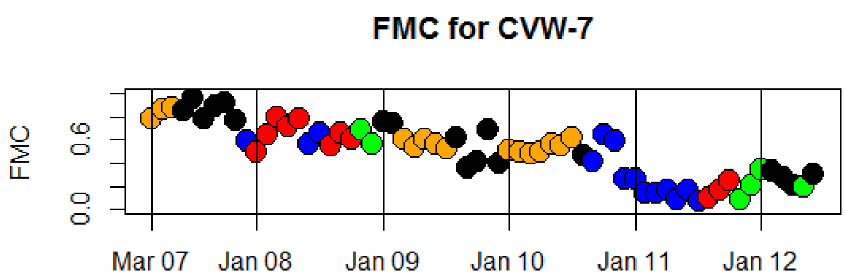
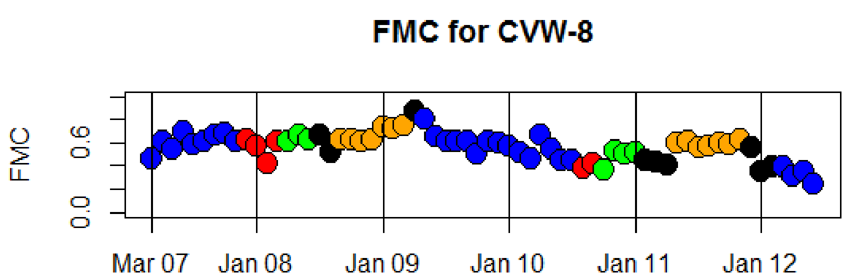

FMC for CVW-7
FMC
0.0
0.6
Mar 07
Jan 08
Jan 09
Jan 10
Jan 11
Jan 12


FMC for CVW-8
FMC
0.0
0.6
Mar 07
Jan 08
Jan 09
Jan 10
Jan 11
Jan 12

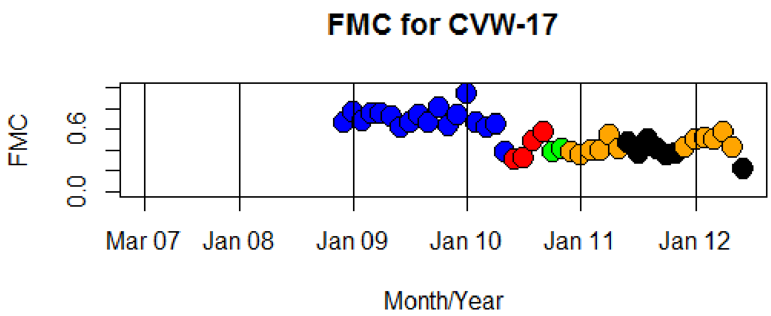


Figure 16. FMC Rates for All Wings

None of the other variables seem to have a substantial relationship with time (all have a correlation with time less than 0.10). Figure 17 presents a stronger FMC and RBA relationship (0.53) within CVW-7 compared with the overall wing results (0.25). RBA is low during POM and holiday leave periods (November and December).

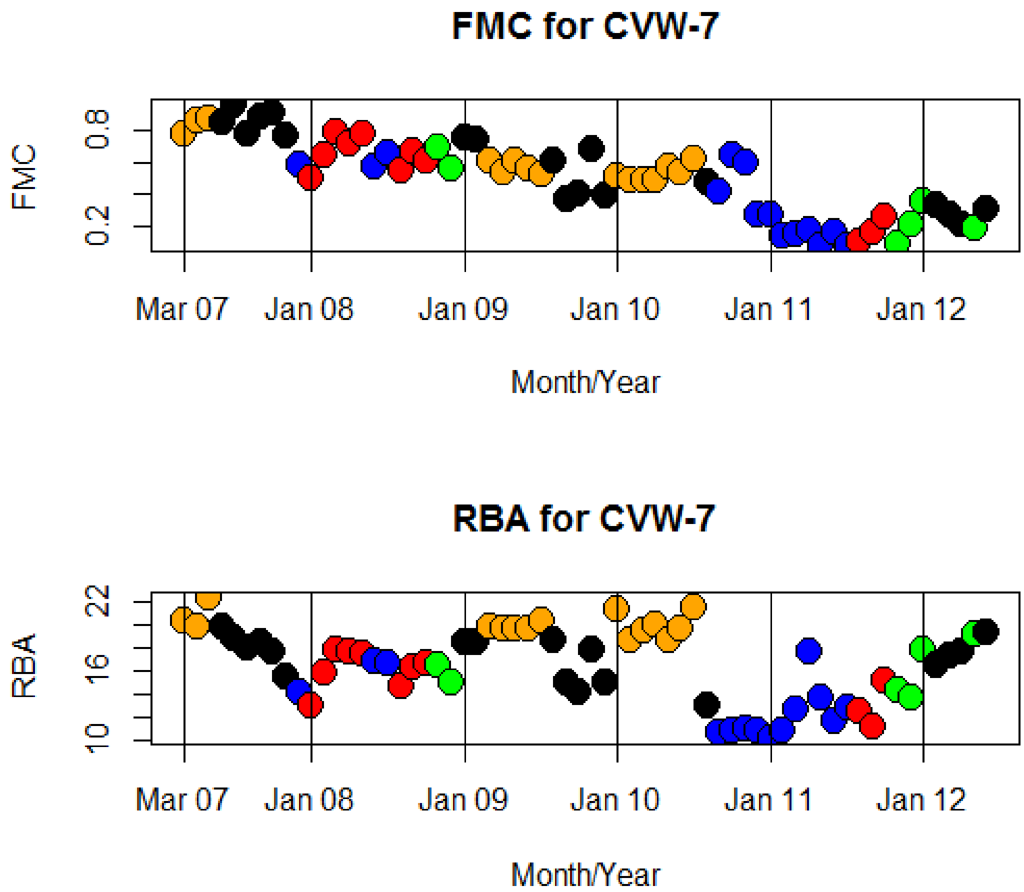


Figure 17. FMC and RBA for CVW-7 (Correlation Coefficient = 0.53 for FMC and RBA)

E. RFT ACTUAL AND RFT ENTITLED

RFT Actual has a very strong positive linear relationship with several variables including RFT Entitled (0.99), TFHR Entitled (0.98), FHRS Entitled (0.96), FLA Entitled (0.93), and RBA (0.90). A marked relationship exists with FLA (0.86) and Assigned A/C (0.82). RFT Actual trends closely with RFT Entitled as a result of the finding from Chapter III that 72.4% of wing/month combinations achieved a perfect RFT = 1.00 (where RFT Actual equals RFT Entitled). Since more flight hours required for training and mission accomplishment generate an increase in demand for RFT A/C, the variables RFT Actual, TFHR Entitled, and FHRS Entitled are strongly related with one another. Similarly as the number of A/C required increases, the number of A/C assigned to the

flight line increases as well as Assigned A/C. The more A/C a wing has, the more A/C there are available to achieve RFT. Finally, an A/C is required to be RBA before it can achieve RFT. Figure 18 illustrates the very dependable relationship between RFT Actual and RFT Entitled for CVW-8 (0.96). During the Maintenance Phase RFT requirements are at their lowest (with the exception of the POM periods); RFT Entitled trends up until Deployment and falls off following Deployment.

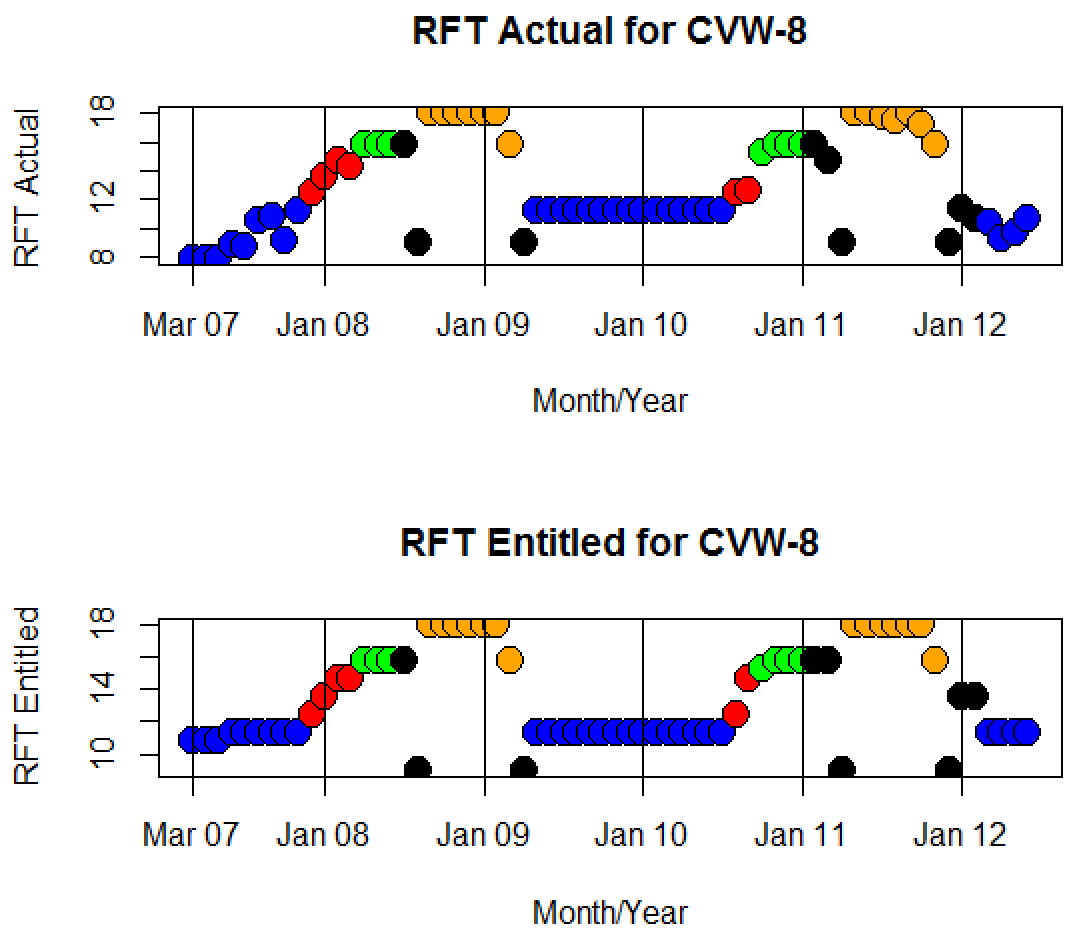


Figure 18. RFT Actual and RFT Entitled for CVW-8 (Correlation Coefficient = 0.96)

F. RFT ENTITLED AND TFHR ENTITLED

RFT Entitled has a very strong positive linear relationship with several variables including TFHR Entitled (0.99), FHRS Entitled (0.96), and FLA Entitled (0.93). A marked relationship exists with RBA (0.89), FLA (0.86) and Assigned A/C (0.83) and this is by design. The relationship between RFT Entitled and TFHR Entitled is nearly perfect, so the flight hours required for training increases linearly with the RFT entitlement. Entitlements are located within the COMNAVAIRFOR INSTRUCTION 3510 series and they are driven by the month/phase within the FRTP (Commander, Naval Air Forces 2006), thus there should be high correlations between all entitlements. For this dataset of 293 observations every increase of one RFT Entitled led to approximately 40.8 TFHR Entitled. Figure 19 presents the strong relationship between RFT Entitled and TFHR Entitled for CVW-3 (0.99). During the Maintenance Phase TFHR requirements are at their lowest; TFHR Entitled trends up until Deployment and falls off following Deployment. Requirements are also very low during the POM periods.

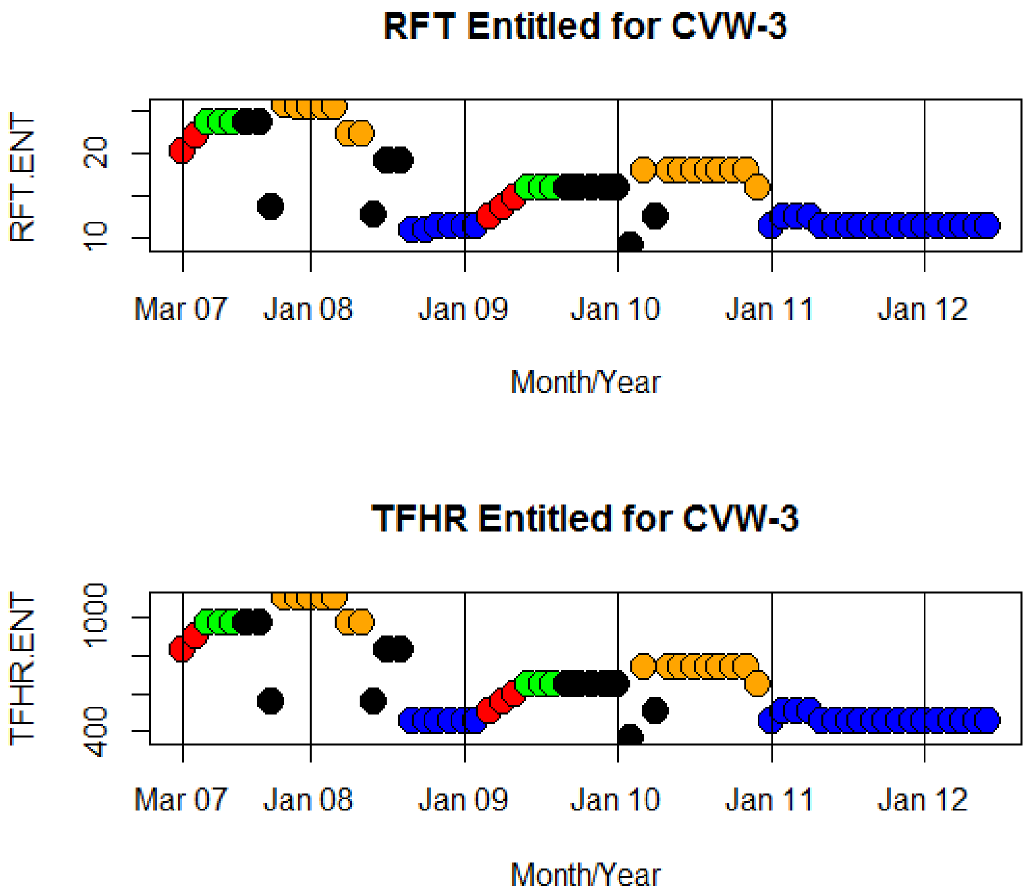


Figure 19. RFT Entitled and TFHR Entitled for CVW-3 (Correlation Coefficient = 0.99)

G. TFHR ENTITLED, FHRS ENTITLED, AND FHA

A very strong positive linear relationship exists between TFHR Entitled and FHRS Entitled (0.99) since TFHR Entitled is a subset of FHRS Entitled, and this is by design. The same cannot be said regarding the relationship between FHA and either entitlement. The largest correlation exists between FHA and FHRS Entitlement (0.56) implying the relationship is substantial, but not significant enough to be very dependable. (FHA and TFHR Entitled yield a 0.48 correlation which is also substantial but not highly dependable). Figure 20 presents plots of FHA, FHRS Entitled, and TFHR Entitled for CVW-8 representative of the typical wing. The Operational Tempo (OPTEMPO) is highest during Deployment, and when on deployment the majority of flight hours are

accrued on-station, while fewer hours are flown in the transits to and from the Operating Area (OPAREA). Requirements are low during POM and holiday leave periods (November and December). Note how closely FHRS Entitled and TFHR Entitled trend with one another (in accordance with the high correlation between the two) and how flight hours tend to increase as a wing prepares for deployment while decreasing post-deployment, with the Maintenance Phase requiring the fewest flight hours.

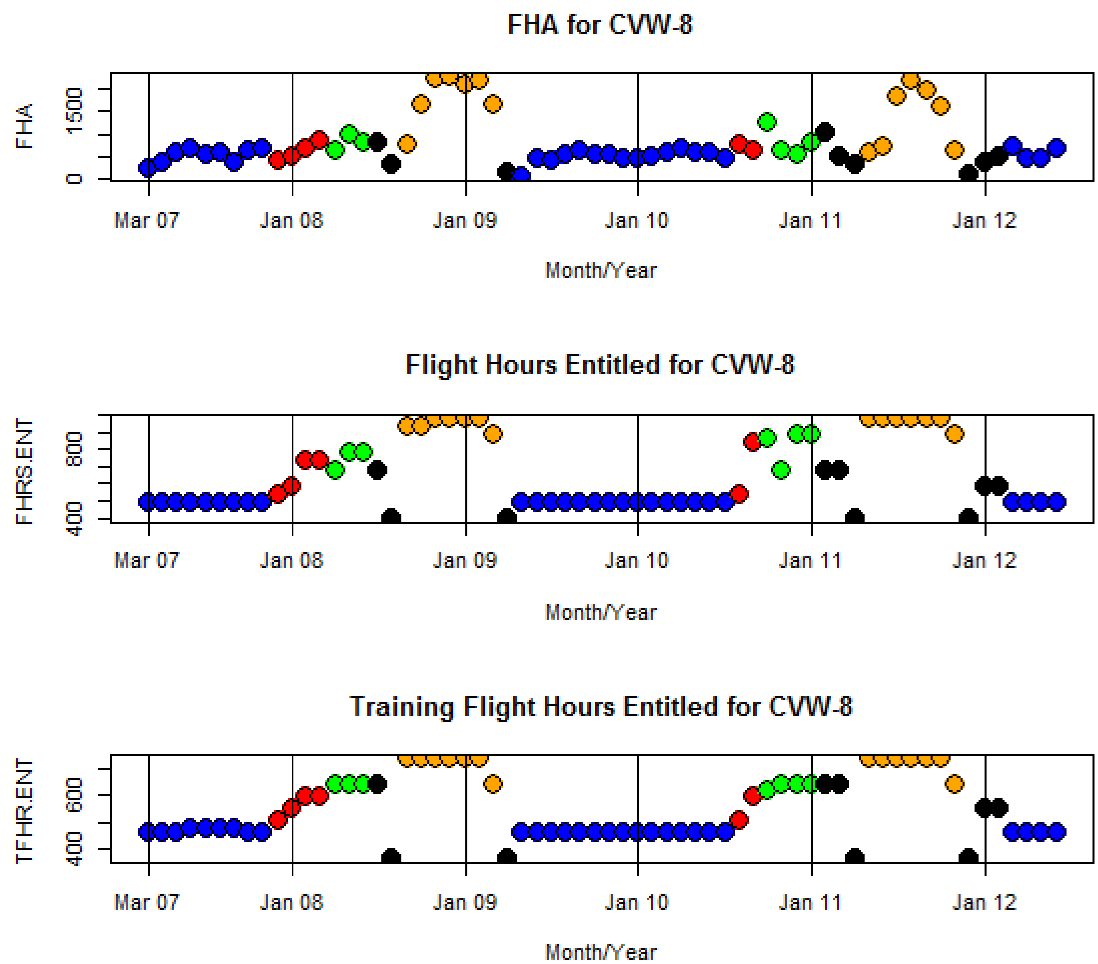


Figure 20. FHA, FHRS Entitled, and TFHR Entitled for CVW-8

H. FHRS ENTITLED AND FLA ENTITLED

FHRS Entitled has a very strong positive linear relationship with several variables including FLA Entitled (0.90). A marked relationship exists with RBA (0.84), FLA (0.78), and Assigned A/C (0.71). These relationships are by design. Figure 21 illustrates the strong relationship between FHRS Entitled and FLA Entitled for CVW-8 (0.82). Like most variables previously discussed, there is a definite cyclical trend for FLA Entitled.

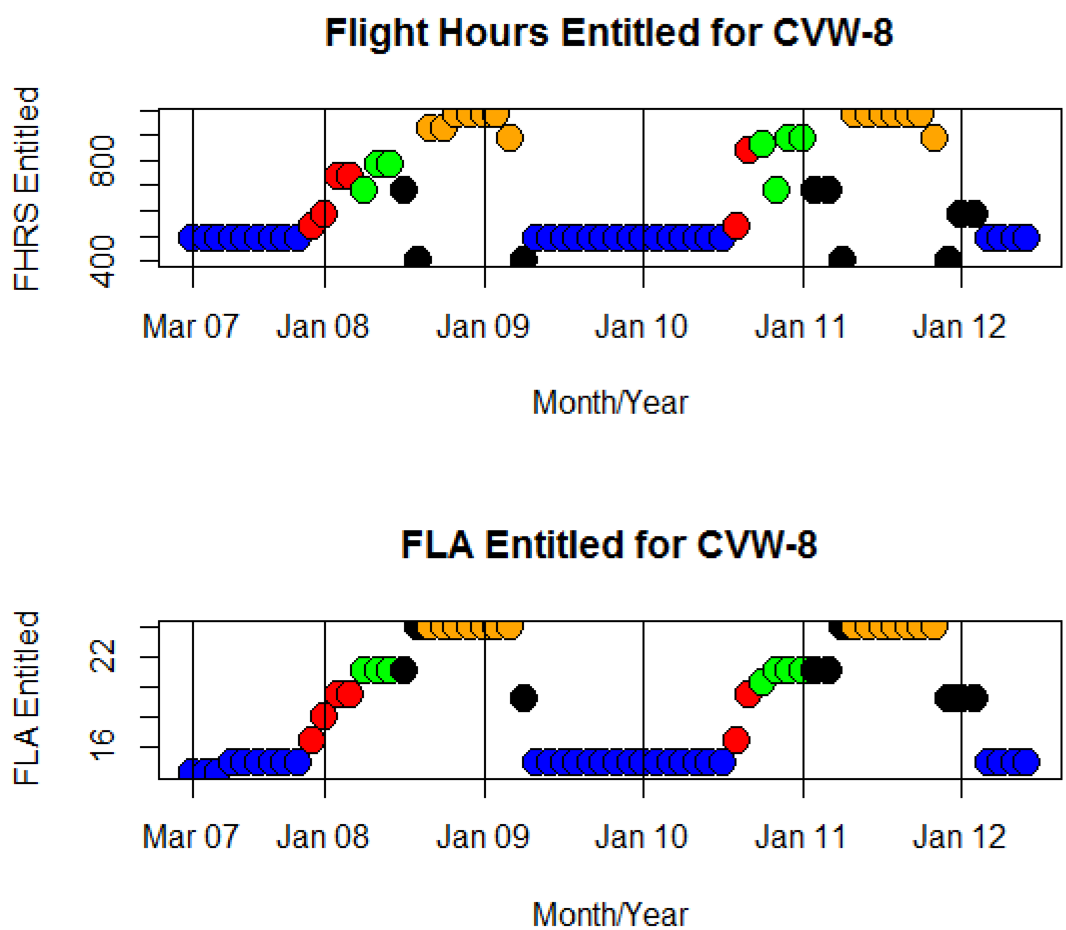


Figure 21. FHRS Entitled and FLA Entitled for CVW-8 (Correlation Coefficient = 0.82)

I. FLA ENTITLED AND RBA

FLA Entitled has a very strong positive linear relationship with several variables including RBA (0.92) and FLA (0.90). A marked relationship exists with Assigned A/C (0.85). As more A/C are required on the flight line, more A/C are available to fly safely (RBA). Figure 22 presents the strong relationship between FLA Entitled and RBA for CVW-3 (0.92).

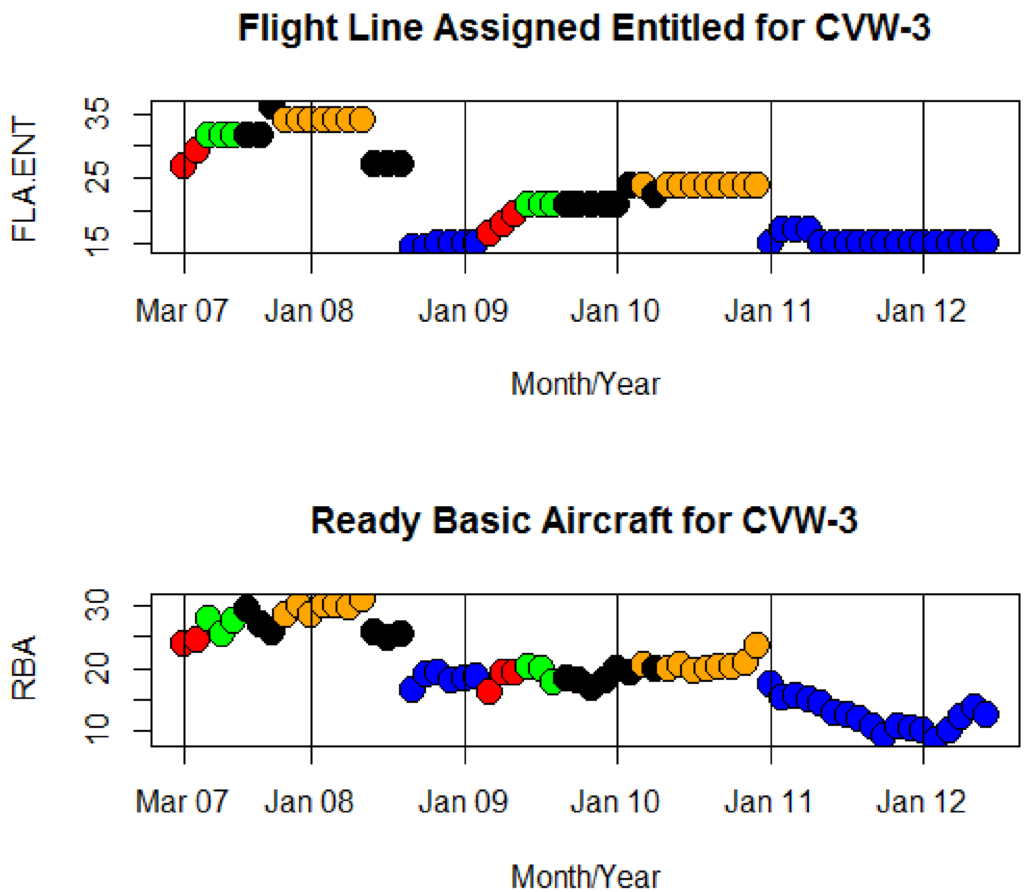


Figure 22. FLA Entitled and RBA for CVW-3 (Correlation Coefficient = 0.92)

J. RBA AND FLA

RBA has a very dependable relationship with several variables including FLA (0.94). A marked relationship exists with Assigned A/C (0.86). Figure 23 presents the strong relationship between RBA and FLA for CVW-3 (0.94).

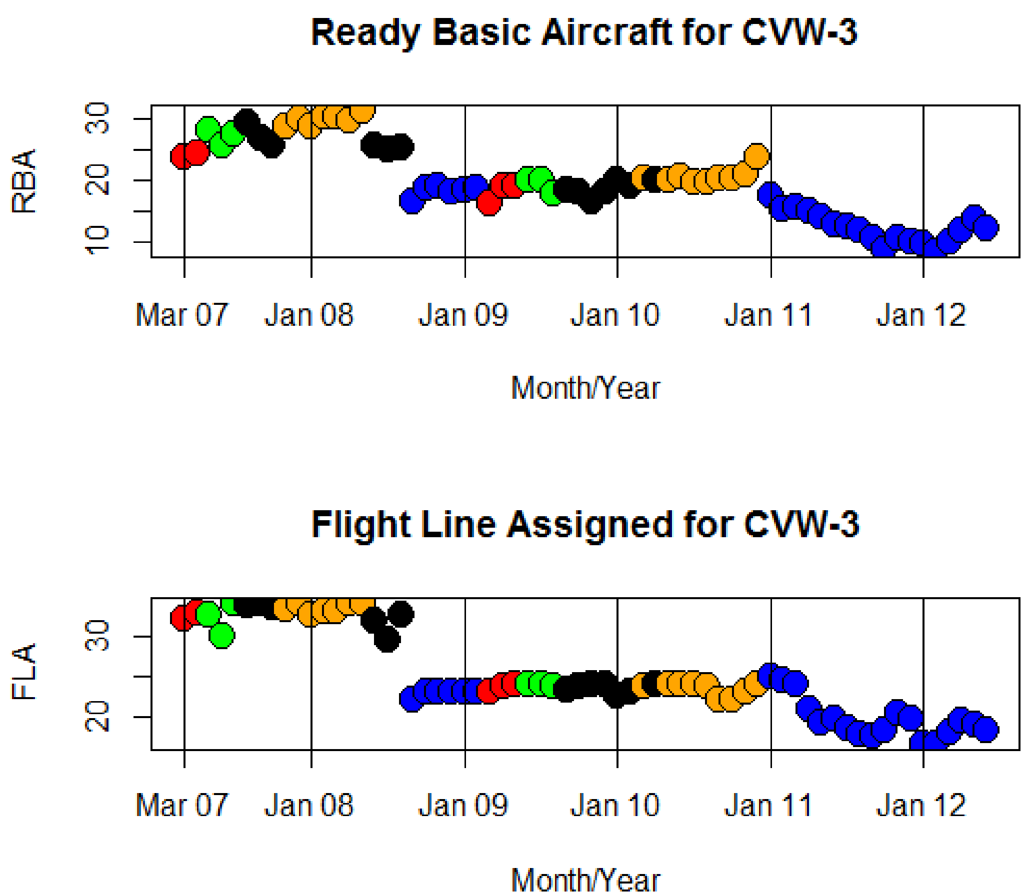


Figure 23. RBA and FLA for CVW-3 (Correlation Coefficient = 0.94)

K. FLA, FLA ENTITLED, AND ASSIGNED A/C

The FLA Entitlement can be regarded as the standard or minimum number of A/C required on the flight line. The Assigned A/C is the number of A/C present in the wing, while the FLA is the number of A/C assigned to the wing's flight line. A/C experience down-time due to maintenance, awaiting parts, repairs, etc., thus squadrons are typically

outfit with enough A/C to compensate for these down-times while still meeting the FLA Entitlement. The FLA is no less than the FLA Entitlement since the entitlement represents the minimum. As a result, the FLA standard (minimum) should be no greater than the FLA, while the FLA should be no greater than the Assigned A/C. Intuition would lead one to believe Assigned A/C, FLA, and FLA Entitled should be very strongly correlated since all three metrics are different ways of representing the number of A/C allocated to wings and indeed this is the case: the highest correlation coefficient for Assigned A/C is with FLA (0.96) and the highest correlation for FLA is with Assigned A/C (0.96). FLA Entitled has a 0.91 correlation with FLA and a 0.86 correlation with Assigned A/C.

Figure 24 presents scatterplots of FLA, FLA Entitled, and Assigned A/C for CVW-1. These variables tend to remain fairly constant as the physical transfers of A/C into and out of squadrons are minimized due to cost and operational implications. Assigned A/C depends largely upon the number of Super Hornet squadrons within the wing, with each squadron on average providing 12 A/C. All wings within the dataset employed one to three squadrons, and CVW-1 in particular carried one squadron (VFA-211) until July 2007 when VFA-136 was temporarily assigned for one month. In July 2008 CVW-1 permanently gained VFA-136 while gaining VFA-11 from CVW-3.

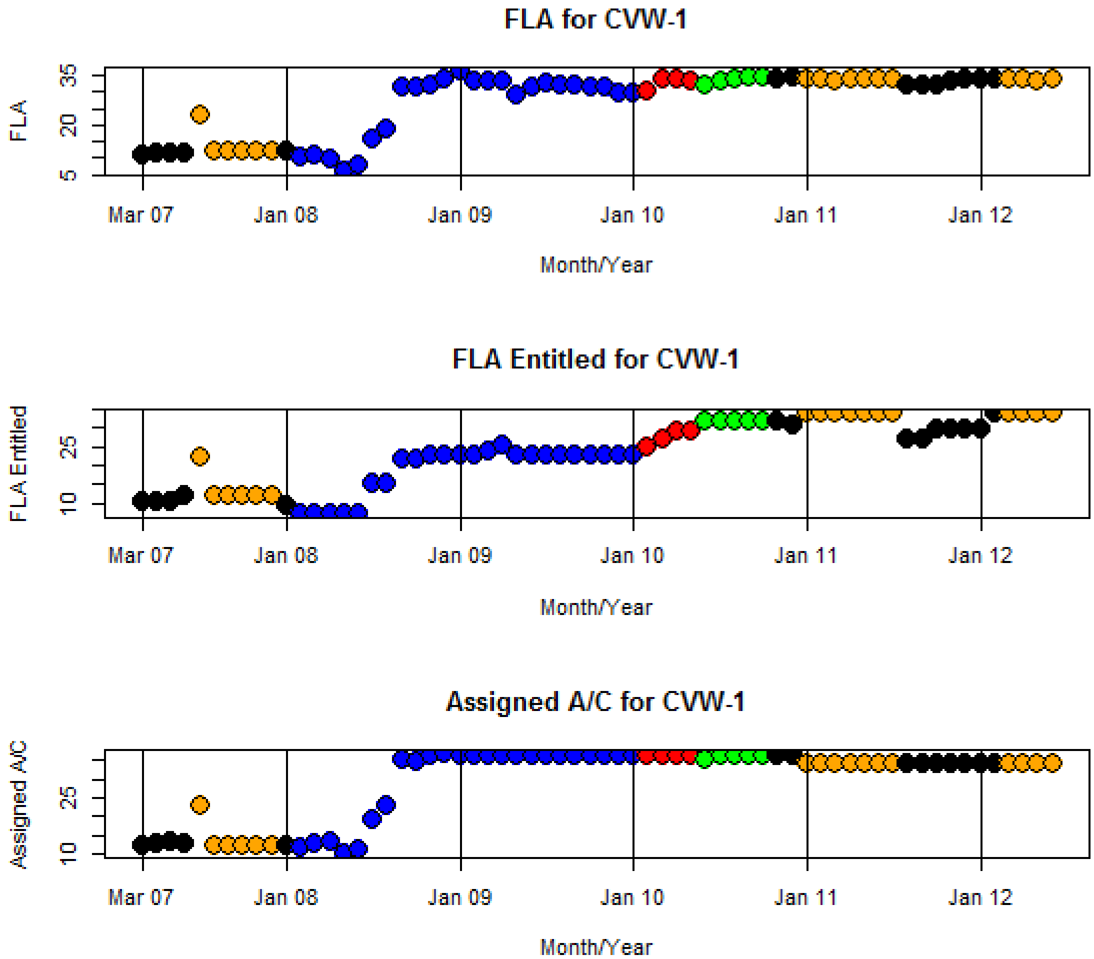


Figure 24. FLA, FLA Entitled, and Assigned A/C for CVW-1

L. ASSIGNED A/C AND FHA

Assigned A/C only has a very dependable relationship with FLA (0.96) while it has marked relationships with several variables as previously presented this chapter. It has a negligible relationship with FHA (0.19), RFT (0.10), and FMC (-0.05). Figure 25 presents plots of Assigned A/C and FHA for CVW-8 (0.23). As expected, flight hours are highest during Deployment and lowest during Maintenance and POM periods. Within the Deployment Phase the transits to and from the OPAREA require fewer flight hours compared with the months when the aircraft carrier is on station.

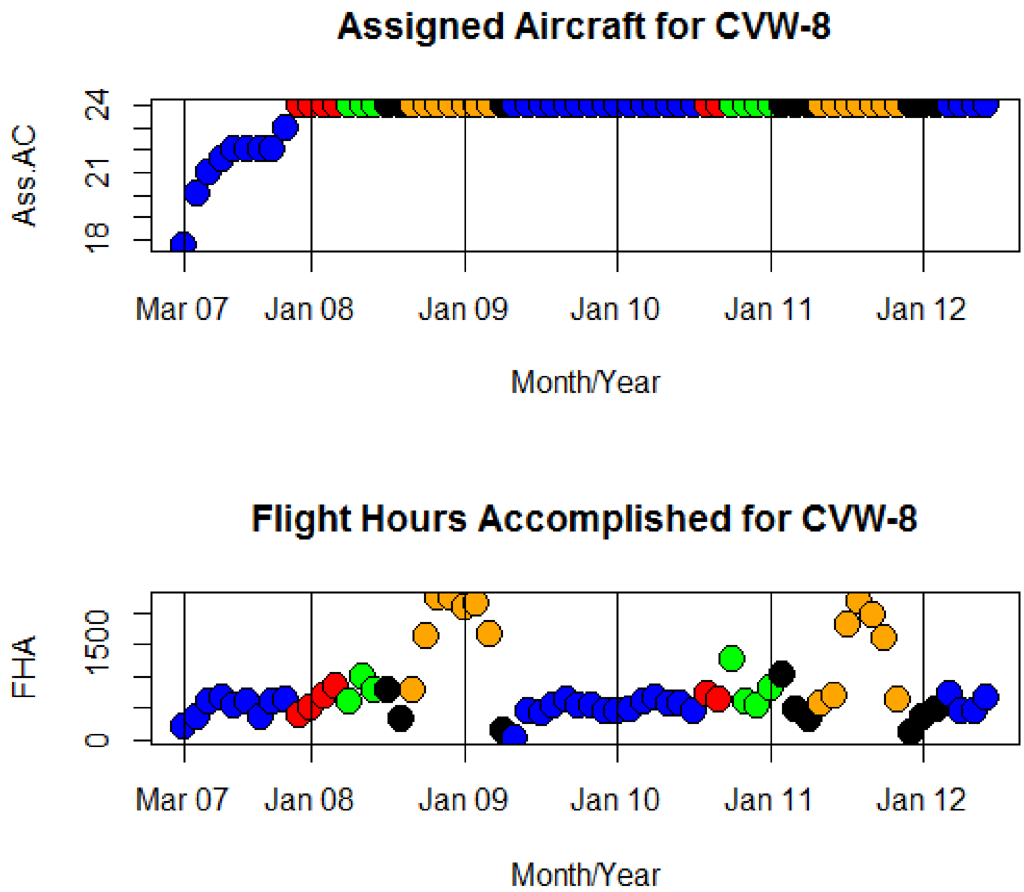


Figure 25. Assigned A/C and FHA for CVW-8 (Correlation Coefficient = 0.23)

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V. MODELING ANALYSIS

A. OBJECTIVE

The previous chapter studied the relationships variables have with one another and their trends during the FRTP. In this chapter we will fit two models to provide insight into the combined effects of the variables on RFT. One model will fit a logistic regression to predict when a wing will achieve a perfect 1.00 RFT for a particular month. The second model will utilize a multiple regression approach incorporating only those observations of RFT falling below 1.00. Taken together these two models provide a mixture model of RFT as a function of the 11 variables considered in this thesis. As noted earlier, it is extremely rare but possible for RFT to be below FMC during a month. However, this dataset contained six observations where RFT was significantly below FMC without a reasonable explanation beyond errors in the respective values reported. Thus, these six anomalies were removed from the dataset and 293 observations remained for analysis. The removed observations are: CVW-1 May 2008, CVW-3 March 2007, and CVW-17 October 2009 through January 2010.

B. LOGISTIC REGRESSION MODEL

The commander's goal each month is to achieve a perfect RFT (1.00). If there are any days where a 1.00 RFT is not achieved, the commander will fall short of the monthly 1.00 RFT goal. Anything below 1.00 RFT is below goal, therefore it is useful to incorporate a model which predicts whether a wing will achieve a 1.00 RFT during a month and a logistic regression model is produced for this purpose. Within the dataset a binary variable replaces RFT % with 1 being assigned when a perfect RFT is achieved (success) and 0 being assigned otherwise (failure).

Observations of 1.00 RFT correspond to higher averages of all variables than observations below 1.00 RFT (Table 13). While wing commanders always endeavor to achieve a perfect RFT, they are most concerned with achieving maximum readiness during deployments and least concerned during the Maintenance Phase and the results bear this out (Table 14). CVW-17 performed the best using the percentage of months

achieving a perfect RFT as the readiness metric (Table 15). Note that in Chapter III, with Fisher's Test at a 5% significance level, neither the phase nor the wing showed systematic differences in the ability to achieve either the FMC standard or the RFT goal. Knowing the wing (without the phase) does not help one predict whether FMC and/or RFT will be met, while knowing the phase (without the wing) is not helpful either. The combination of the wing and the phase is significant though for certain wings/phases.

Variable	RFT < 1.00	RFT = 1.00
Ready for Tasking Entitled	13.58	14.20
RFT Achieved	12.37	14.20
RFT Percentage	0.90	1.00
Full Mission Capable	0.49	0.53
Ready Basic A/C	14.60	18.04
Assigned A/C	23.44	24.16
FLA Entitled	18.39	19.98
Flight Line Assigned	20.68	23.04
Flight Hours Entitled	640.13	710.68
Flight Hours Accomplished	773.57	865.08
Training Flight Hours Entitled	561.50	587.35

Table 13. Average Values of Variables when RFT < 1.00 and when RFT = 1.00

Phase	% Months Where RFT = 1.00	RFT = 1.00/# Months in Phase
Deployed	0.81	60/74
Sustain	0.77	47/61
Basic	0.76	22/29
Intermediate	0.65	17/26
Maintain	0.64	66/103

Table 14. Percentage of Months where RFT = 1.00 by Phase

Wing	% Months Where RFT = 1.00	RFT = 1.00/# Months for Wing
CVW-17	0.87	34/39
CVW-3	0.78	49/63
CVW-8	0.69	44/64
CVW-7	0.67	43/64
CVW-1	0.67	42/63

Table 15. Percentage of Months where RFT = 1.00 by Wing

The naïve Bayes' rule implies one has a 72.4% chance of predicting correctly whether a 1.00 RFT was achieved during a given month by predicting "yes" each time, yielding 212 out of 293 accurate predictions. Any useful logistic regression model must predict correctly at a rate greater than 72.4% for this dataset.

The logistic regression model considered the following variables (in parenthesis are the terms used in the R program): FLA, Assigned A/C (Ass.AC), Wing, Phase, FMC, FLA Entitled (FLA.ENT), RFT Entitled (RFT.ENT), TFHR Entitled (TFHR.ENT), FHRS Entitled (FHRS.ENT), RBA, and FHA. RFT Achieved was not considered since RFT % is RFT Achieved divided by RFT.ENT and RFT.ENT was under consideration. A generalized additive model with a logistic link function and a Bernoulli response variable was applied utilizing smoothers for the numerical variables and the partial residuals were plotted to determine potential transformations of these variables (Venables and Ripley 2002). None of the numeric variables required transformation. A logistic regression model was then applied to these variables followed by stepwise selection based on Akaike's Information Criterion (AIC) to include potentially important interaction terms and remove redundant or unimportant terms. The stepAIC function of the R package MASS was utilized and details of the model fit are in Appendix A (Venables and Ripley 2002).

The model includes RBA, Ass.AC, FHRS.ENT, TFHR.ENT, FLA.ENT, FMC, and Wing in addition to interactions between Ass.AC:Wing, FMC:Wing, and FHRS.ENT:FMC. Phase fell out of this model; hence Phase did not affect a wing's ability to achieve a perfect monthly RFT when including the other variables. "Including

the other variables" is a key distinction as we discovered via Fisher's Test that CVW-1 and CVW-7's RFT performance was affected by Phase in isolation. Thus there are other variables with relationships involving Phase (recall entitlements are driven by month/phase and number of A/C) that enable Phase to be omitted from the final model. FLA and RFT.ENT fell out of the model due to their extremely high correlations with Ass.AC (0.96) and TFHR.ENT (0.99) respectively, while the model also does not require FHA.

Ten-fold cross-validation (see e.g. Montgomery et al. 2006) was used to estimate the misclassification rate for the logistic regression model. In cross-validation the observations are randomly partitioned into 10 subsets of approximately equal numbers. The model is fit to each subset and the fraction of observations misclassified is computed. The total misclassification rate is the average of all 10 misclassification fractions. A misclassification can either occur when the model predicts a 1 (determined when the estimated probability exceeds 0.5) and a 0 results or when the model predicts a 0 (estimated probability is less than or equal to 0.5) and a 1 results. Using this method with the model and dataset misclassified 16.37% of observations. Utilizing the naïve Bayes rule and predicting a 1 for all observations would misclassify 27.6% of observations so this logistic regression model improves predictive capabilities: the model reduces the misclassification rate by 40.7% compared with the naïve Bayes rule.

The empirical misclassification rate (using all observations) was 11.95%. There were 24 false positives where a 1 was predicted but a 0 was achieved and 11 false negatives where a 0 was predicted while a 1 was achieved. For each wing the logistic regression model predicted more accurately than the naïve Bayes rule. Ten of 35 misclassifications occurred when the probability was between 0.40 and 0.60 and hence the confidence of these predictions was not very high. Fifteen misclassifications had large leverages while 12 had large R-Student residuals. The largest Cook's Distance and the largest leverage occurred during the same observation (values were 0.291 and 0.630 respectively, occasion resulted in a false negative) thus no observations were influential. The largest absolute value for R-Student residuals was 3.54 and this observation registered a false positive. See Montgomery et al. (2006) for a discussion on how the statistics R-Student residuals, leverages, and Cook's Distances are used to identify unusual and influential observations.

C. MODEL EXCLUDING PERFECT READY FOR TASKINGS

Upon removal of the six anomalies, 81 of 293 remaining observations achieved an RFT below 1.00 (27.6%) for a given month. In this section, we fit a multiple regression to these 81 observations. The correlation between RFT and FMC is higher (0.26 vs. 0.17) when observations where RFT = 1.00 are excluded, although the relationship is still not a strong one. 77.3% of the pairwise correlations were stronger with the dataset excluding RFT = 1.00, but most of those differences were marginal.

The following variables are used: FHA, RBA, FLA, Assigned A/C (Ass.AC), FHRS Entitled (FHRS.ENT), TFHR Entitled (TFHR.ENT), RFT Entitled (RFT.ENT), FLA Entitled (FLA.ENT), FMC, Wing, and Phase. After fitting a multiple regression of RFT modeled by all variables, residual diagnostic plots uncovered unequal variance: as predicted RFT increases the variability of the residuals decreases (Figure 26). There is a simple explanation for this. The maximum RFT by definition is 1.00, however the predicted RFT can exceed 1.00. Since the residual is calculated as the predicted RFT subtracted from observed RFT, when the predicted RFT is 0.85 the maximum residual is 0.15 and when the predicted RFT is 0.95 the maximum residual is 0.05. This explains why the spread in the residuals is greater for predicted values around 0.85 than it is when predicted values are around 0.95.

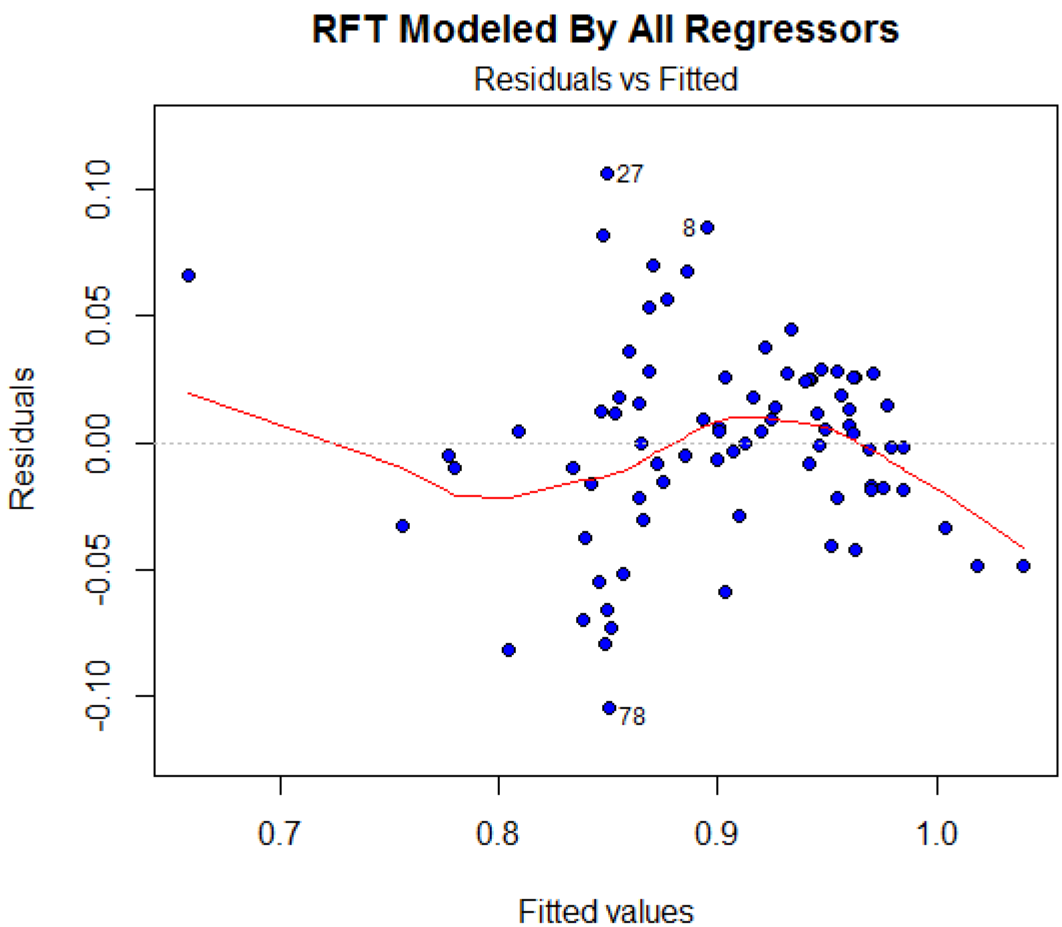

Figure 26. Plot of Residuals vs. Predicted Fitted Values for Model without Transformation

To resolve the unequal variance issue we considered transforming the dependent variable RFT by the square root of (1-RFT), the log of (1-RFT), and the log odds (log of RFT/(1-RFT). The square root transformation yielded the best results and now we have a model which has relatively equal variance (Figure 27).

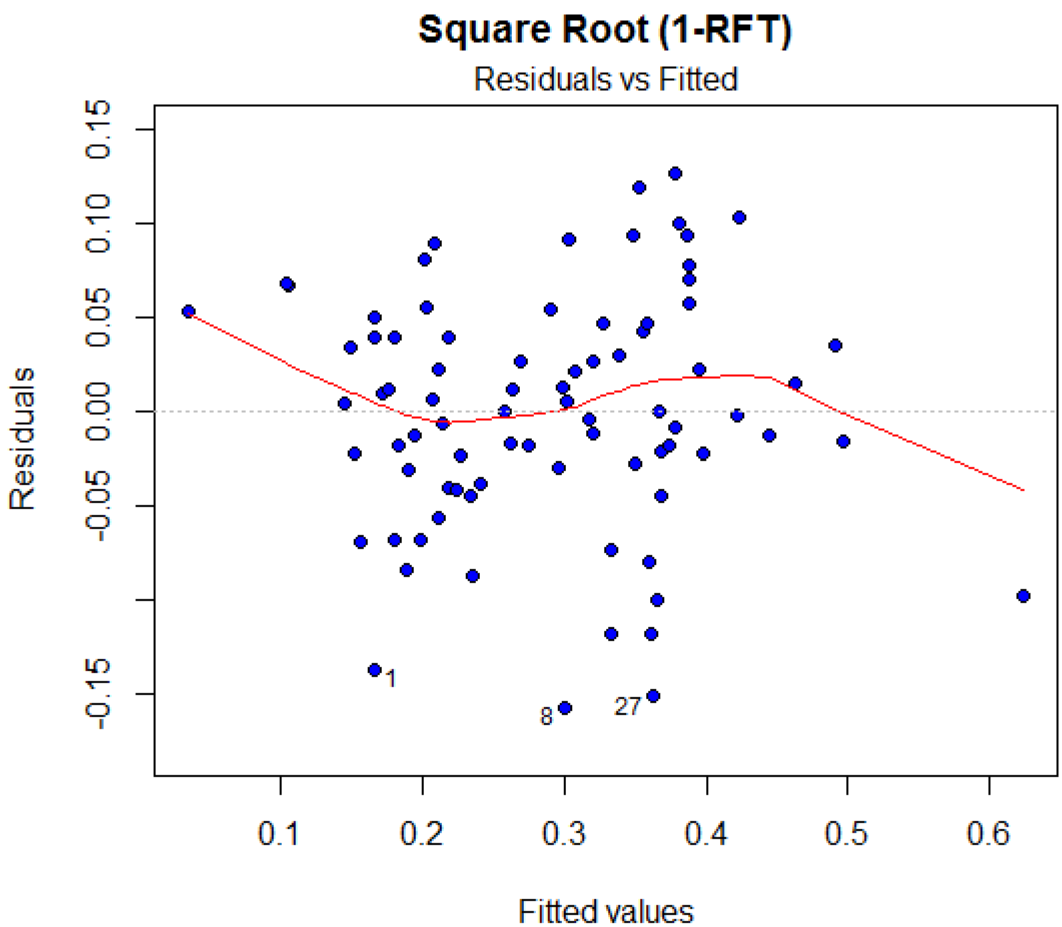

Figure 27. Plot of Residuals vs. Predicted Values for Model with Square Root (1-RFT) Transformation

Observations 1, 8, and 27 had the highest absolute values for R-Student residuals (maximum absolute value was -0.232 for observation 8) while three observations had large leverages. The largest Cook's Distance and the largest leverage occurred during the same observation (values were 0.599 and 0.958 respectively) thus no observations were influential.

Stepwise selection based on AIC was used to include potentially important interaction terms and remove redundant or unimportant terms. Details of the model fit are in Appendix B. This model omitted FHA and FMC while including only the interactions between Assigned A/C:Wing and FHRS Entitled:Phase. Thus FMC is not

necessary for predicting RFT when utilizing a multiple regression model in the presence of the other variables. In fact, FMC fell out of all four models cited above.

D. DISCUSSION

While predicting when a wing achieves a perfect RFT during a month by employing a logistic regression model, Phase was surprisingly omitted from the best model although Fisher's Test concluded at a 5% significance level that CVW-1 and CVW-7's RFT performance was affected by Phase. Recall the entitlements are located within the CNAF INSTRUCTION 3510 series, and they are driven by the month/phase within the FRTP. The relationships Phase has with other variables (as displayed within the plots in Chapter IV) are strong enough to include those variables in the model in lieu of Phase. FHA fell out of the model, so at an average of $10K per flight hour FHA does not directly impact RFT in the presence of the other variables. When predicting a wing's monthly RFT given the wing was unable to achieve the RFT goal of 1.00, the multiple regression model omitted FMC in the presence of the other variables. FMC lacked a strong correlation with all variables including RFT which may explain its omission. FHA was also unnecessary for this model.

The importance of the models exists in the variables considered necessary (or more appropriately, unnecessary) in the presence of other predictors. The air wing commanders cannot easily manipulate any variables considered within this analysis. The month within the FRTP determines the Phase, the Wing is self-explanatory, and the entitlements can only be adjusted by higher echelons. Increasing Assigned A/C will lead to a rise in FLA, thus there is a larger selection of A/C to draw from to become RFT. However, increasing the Assigned A/C is expensive and there is an opportunity cost associated with reallocating A/C from other wings in support of a specific wing's RFT goal. Similarly to RFT, FMC and RBA are readiness metrics computed at the end of the month so there is no forecasting potential with FMC or RBA.

Finally only Super Hornets supported via NAS Oceana during March 2007 through June 2012 were considered for this analysis. Alternative T/M/S, support locations, or time frames may produce contradicting conclusions.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. Correlation of RFT to FMC is Small but Inconclusive

The correlation between RFT and FMC is only 0.17, which demonstrates a small but inconclusive relationship. In fact both CVW-1 and CVW-17 had negative correlation coefficients: as RFT improved, FMC declined (Devore, 2012). RFT and FMC as fractions are not measuring the same aspects of readiness: while all FMC A/C are included in FMC calculations as a fraction, only A/C rated RFT up to the number of RFT Entitled are included in the RFT fractional calculation.

2. RFT and FMC were not Systematically Affected by Wing or Phase

We found that neither the phase nor the wing showed systematic differences in the ability to achieve either the FMC standard or the RFT goal when evaluated as a whole. Knowing the wing (without the phase) does not help one predict whether FMC and/or RFT will be met, while knowing the phase (without the wing) is not helpful either. The combination of the wing and the phase is significant though for certain wings/phases as shown in Chapter III. Specifically, phase mattered in the accomplishment of FMC for CVW-3 and CVW-17 while phase was a factor in the achievement of a perfect monthly RFT for CVW-1 and CVW-7.

3. FMC Presents a Clearer Readiness Trend than RFT

There are trends one can detect with the FMC plots that cannot be observed from RFT, including the finding that the readiness of wings tends to trend upward leading to deployment while falling off post-deployment. There appears to be value in retaining both metrics: if the primary concern is accomplishing missions when required then RFT has a purpose, while FMC is useful to portray readiness trends and as a funding input. Employing RFT as an input for aviation spares funding models could have significant fiscal effects if a perfect RFT is the goal since this thesis found 72.4% of observations

meeting the goal. Previous studies have addressed the trends with FMC and funding and the ARROWs model already utilizes FMC as an input.

4. "Lies, Damned Lies, and Statistics"

Mark Twain is credited with "Lies, Damned Lies, and Statistics" and based upon the image we wish to portray, we can generate several conclusions from the same dataset by selecting FMC or RFT as the metric of choice. If achieving an RFT of 1.00 during deployment is the ultimate goal, CVW-17 had the highest readiness of the five East Coast air wings during this five year period. However, if meeting an FMC standard of 0.63 during deployment is the measuring stick, CVW-17 had the worst readiness. Thus it is critical to select an appropriate readiness metric and while the commander may simply desire to accomplish the mission, one can better detect trends and patterns with FMC than via RFT.

5. FMC's Negative Trend over Time

FMC had a stronger relationship with time (correlation coefficient of -0.60), where time is measured by the month/year, than any variable considered during this analysis. FHA had the next largest correlation (0.10) with time and this represents an undetermined linear relationship. This finding supports the results from LMI's September 2011 study concluding a negative trend in FMC values for overall T/M/S A/C since 2006 (Buckley et al. 2011). Table 16 presents the rates wings met the FMC standards by year. Beginning in 2008 the overall FMC accomplishment rate has declined each year and during the first six months of 2012 none of the wings met their FMC standards (0.53 non-deployed, 0.63 deployed). Fisher's Test supports the conclusion that overall FMC is declining beyond what would be expected by chance. CVWs 7, 8, and 17 are in a declining trend while CVW-1 has been consistently missing the mark throughout with the exception of 2008. Statistically speaking, 2008 was an anomaly for CVW-1: without 2008 there would not have been a difference between the years.

Year						
	2007	**2008**	**2009**	**2010**	**2011**	**2012**
CVW-1	30%	73%	0%	42%	25%	0%
CVW-3	100%	83%	33%	83%	0%	0%
CVW-7	100%	92%	33%	17%	0%	0%
CVW-8	90%	67%	92%	25%	8%	0%
CVW-17	N/A	100%	100%	36%	0%	0%
Overall	79%	79%	49%	41%	7%	0%

Table 16. Rates Wings Met FMC Standards by Year

Table 17 presents the RFT accomplishment rates by year. The correlation between RFT and time (measured in month increments) was -0.01 which is an indefinite linear relationship between the two. At a significance of 5%, CVW-7 and CVW-17 exhibited no difference in RFT accomplishment by year, while the poor performance during the first six months of 2012 helped make the year statistically significant for CVW-3. Consolidating all five wings together, there is not an overall difference in RFT achievement rates by year, while there is an overall decline in FMC achievement.

Year						
	2007	**2008**	**2009**	**2010**	**2011**	**2012**
CVW-1	40%	55%	92%	42%	83%	100%
CVW-3	78%	92%	92%	92%	58%	33%
CVW-7	80%	75%	67%	58%	42%	100%
CVW-8	20%	92%	100%	92%	67%	0%
CVW-17	N/A	0%	78%	100%	83%	100%
Overall	54%	77%	86%	76%	67%	50%

Table 17. Rates Wings Met RFT Goals by Year

6. Impacts of Phase and FMC on Accomplishment of RFT

While predicting when a wing achieves a perfect RFT during a month by employing a logistic regression model, Phase was surprisingly omitted from the best model. The relationships Phase has with other variables (including the entitlements) are strong enough to include those variables in the model in lieu of Phase. FHA also fell out of the model. When predicting a wing's monthly RFT given the wing was unable to

achieve the RFT goal of 1.00, the multiple regression model omitted FMC in the presence of the other variables. FMC lacked a strong correlation with all variables including RFT which may explain its omission. FHA was also unnecessary for this model.

B. RECOMMENDATIONS

1. Retain FMC and RFT Metrics

When utilized as fractions, there appears to be value in retaining both FMC and RFT as metrics: if the primary concern is accomplishing missions when required then RFT has a purpose, while FMC is useful to portray readiness trends and as a funding input.

2. Increase Validity of Data Inputs

The original dataset contained 299 wing/month combinations while the correlation coefficient between RFT and FMC was 0.02. After removing six anomalies due to RFT being significantly less than FMC without explanation, the coefficient increased to 0.17 (0.17 still represents an indefinite relationship). If these six observations' RFTs were greater than the FMCs these input errors would not have been discovered. Of the 293 remaining observations, there could be several that were also input in error and that could have affected these results. The findings from this thesis are only good for this dataset in the sense that this dataset contains accurate data.

C. OPPORTUNITIES FOR FURTHER STUDY

1. Repairable Allowancing

Previous research explored the relationship between APN-6 funding and FMC rates. Future studies can address the relationship between the APN-6 account and RFT. One could also reconsider the minimum acceptable RFT for mission accomplishment. The average RFT for all observations was 0.97 and during 72.4% of months a wing achieved an RFT of 1.00. Of those months where a wing fell short of a perfect RFT, the average RFT was 0.90. If RFT is to be used as the true readiness indicator, reevaluating the acceptable RFT goal could impact the level for adequate repairable spares funding.

2. Supply Material Availability

Originally, this thesis was designed to factor in as much emphasis on Supply Material Availability (SMA) at the retail level as RFT and FMC. Due to time constraints we were unable to obtain the SMA fill rate data for this analysis. Utilizing the work provided within this thesis, future studies can tie in fill rate data to discover the relationships RFT has with fill rates and to determine if fill rates are required in either model to predict RFT. Similarly to FMC and RBA, fill rates are computed at the end of the month thus SMA is unable to forecast RFT achievement.

3. West Coast Squadrons and Alternative T/M/S

This thesis only utilized Super Hornets supported via NAS Oceana during March 2007 through June 2012. Alternative T/M/S, support locations, or time frames may produce different conclusions. Super Hornets on the east coast have experienced declining FMC rates and it would be interesting to discover whether West Coast Super Hornets reflect similar relationships between RFT and the variables considered within this analysis.

4. RFT Achievement by Mission

The RFT data was collected at the monthly level and this thesis did not explore the specific missions preventing A/C from achieving the RFT goal during a given day. It would be useful to examine RFT success by required mission sets to determine if there are mission sets with high demands that are experiencing more failures than others. In addition, the mission sets could be considered categorical variables and included within the dataset to discover whether they are significant in multiple or logistic regression models.

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APPENDIX A. THE LOGISTIC REGRESSION COEFFICIENTS AND STANDARD ERRORS

```
glm(formula = Bernoulli ~ RBA + Ass.AC + FHRS.ENT + TFHR.ENT +
    FLA.ENT + FMC + Wing + Ass.AC:Wing + FMC:Wing + FHRS.ENT:FMC,
    family = "binomial", data = Bernoulli.data)

Residuals:
     Min          1Q     Median       3Q       Max
  -3.3214    -0.0939    0.2061    0.4968    2.5350

Coefficients:
                          Estimate   Std. Error   t value      Pr(>|t|)
(Intercept)             -1.063e+02   3.111e+01   -3.417     0.000634 ***
RBA                     -1.125e+00   1.734e-01   -6.490     8.58e-11 ***
Ass.AC                   3.956e+00   1.257e+00    3.148     0.001645 **
FHRS.ENT                 9.719e-03   4.029e-03    2.412     0.015852 *
TFHR.ENT                -1.888e-02   5.231e-03   -3.610     0.000306 ***
FLA.ENT                 -3.249e-01   1.271e-01   -2.557     0.010549 *
FMC                      1.534e+01   5.919e+00    2.592     0.009543 **
WingOne                  1.075e+02   3.103e+01    3.464     0.000531 ***
WingSeven                8.021e+01   3.468e+01    2.313     0.020745 *
WingSeventeen            1.145e+02   3.196e+01    3.581     0.000343 ***
WingThree                1.058e+02   3.097e+01    3.415     0.000637 ***
Ass.AC:WingOne          -4.137e+00   1.253e+00   -3.300     0.000965 ***
Ass.AC:WingSeven        -3.104e+00   1.402e+00   -2.214     0.026828 *
Ass.AC:WingSeventeen    -4.408e+00   1.320e+00   -3.338     0.000844 ***
Ass.AC:WingThree        -4.095e+00   1.255e+00   -3.263     0.001102 **
FMC:WingOne             -1.667e+01   5.970e+00   -2.793     0.005224 **
FMC:WingSeven           -1.031e+01   5.115e+00   -2.016     0.043759 *
FMC:WingSeventeen       -2.215e+01   7.090e+00   -3.124     0.001785 **
FMC:WingThree           -1.340e+01   5.631e+00   -2.379     0.017338 *
FHRS.ENT:FMC            -9.522e-03   5.325e-03   -1.788     0.073734 .

---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)
Null deviance: 345.49 on 292 degrees of freedom
Residual deviance: 179.94 on 273 degrees of freedom
AIC: 219.94
Number of Fisher Scoring iterations: 7
```

Table 18. The logistic regression fit of the Bernoulli variable against seven variables and three interactions. Included are the R function call, the estimates of the coefficients, their standard errors, and other summary statistics.

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APPENDIX B. THE MULTIPLE REGRESSION COEFFICIENTS AND STANDARD ERRORS

```
lm(formula = sqrt(1 - RFT.Perc) ~ RBA + FLA + Ass.AC + FHRS.ENT + TFHR.ENT +
    RFT.ENT + FLA.ENT + Wing + Phase + Ass.AC:Wing + FHRS.ENT:Phase,
    data = lessthanone.data)

Residuals:
     Min        1Q    Median       3Q      Max
-0.15689  -0.03048   0.00000  0.04191  0.12631

Coefficients:
                              Estimate  Std. Error  t value    Pr(>|t|)
(Intercept)                  1.0558839   0.3254749    3.244    0.001973 **
RBA                          0.0278127   0.0062531   -4.448    4.07e-05 ***
FLA                          0.0151821   0.0075253    2.017    0.048364 *
Ass.AC                      -0.0549958   0.0117300   -4.688    1.76e-05 ***
FHRS.ENT                     0.0005512   0.0002425    2.273    0.026816 *
TFHR.ENT                     0.0006151   0.0003511    1.752    0.085145 .
RFT.ENT                     -0.0345545   0.0178197   -1.939    0.057443 .
FLA.ENT                      0.0167033   0.0112707    1.482    0.143844
WingOne                     -1.3920544   0.3122414   -4.458    3.93e-05 ***
WingSeven                   -5.2206866   1.1407347   -4.577    2.60e-05 ***
WingSeventeen               -1.3398664   0.3383736   -3.960    0.000211 ***
WingThree                   -1.4773038   0.3549952   -4.161    0.000108 ***
PhaseDeployed                0.5487059   0.1764422    3.110    0.002921 **
PhaseIntermediate            0.2367194   0.2051882    1.154    0.253450
PhaseMaintain                0.6534465   0.1938083    3.372    0.001347 **
PhaseSustain                 0.5183269   0.1945832    2.664    0.010029 *
Ass.AC:WingOne               0.0538844   0.0133020    4.051    0.000156 ***
Ass.AC:WingSeven             0.2181265   0.0476834    4.574    2.62e-05 ***
Ass.AC:WingSeventeen         0.0624248   0.0210809    2.961    0.004461 **
Ass.AC:WingThree             0.0613347   0.0147849    4.148    0.000113 ***
FHRS.ENT:PhaseDeployed      -0.0006886   0.0001944   -3.542    0.000801 ***
FHRS.ENT:PhaseIntermediate  -0.0003692   0.0002317   -1.593    0.116646
FHRS.ENT:PhaseMaintain      -0.0008964   0.0003114   -2.879    0.005607 **
FHRS.ENT:PhaseSustain       -0.0006855   0.0002511   -2.730    0.008422 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.07433 on 57 degrees of freedom
Multiple R-squared: 0.7359, Adjusted R-squared: 0.6293
F-statistic: 6.905 on 23 and 57 DF,  p-value: 1.588e-09
```

Table 19. The multiple regression fit of the transformed RFT.Perc against nine variables and two interactions. Included are the R function call, the estimates of the coefficients, their standard errors, and other summary statistics

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